Karst caves in Haida Gwaii: archaeology and paleontology at the Pleistocene-Holocene transition

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Abstract

Karst cave investigations in the south of Haida Gwaii have opened a small window on human and paleontological components of the early post-glacial landscape. At three cave locations (K1, Gaadu Din 1 and Gaadu Din 2) our investigations recovered a paleontological record extending from ca. 13,400 to 11,000 years ago and a small number of human artifacts dating from ca. 12,600 to 11,000 years ago. The animal bones recovered are dominated by black and brown bear remains, revealing that these caves were being used for winter dens. Other species present include deer, caribou, and salmon. Domestic dog remains with a direct radiocarbon age of 13,100 years ago are the earliest indicator of human presence from the cave assemblages, and are also the earliest known domestic dog remains reported on in the Americas. Brown bear and deer disappear from the paleontological record at the end of the Pleistocene, but other species persist into the Holocene, most of which continue to thrive on the islands to this day, with the exception of caribou which were extirpated in the early 20th Century. The stone tools that we found are predominately spearpoints and fragments thereof, which were used to hunt denning bears. Additional stone tool types from the Gaadu Din Caves reveal that they were occasionally used by humans as temporary shelters. As sea level was lower than today between 13,400 and 11,000 years ago, the caves provide an alternative target for late Pleistocene archaeological prospection that does not involve subtidal work. Our research demonstrates that karst caves on Haida Gwaii provided ecological and cultural focal points during the early post-glacial period. These caves remained sufficiently stable to preserve the residues of activities including bear denning and bear hunting. With the commencement of the Holocene, the record of animal and human use of the three caves diminishes.

Introduction

In the Haida Gwaii-Hecate Strait area, environmental change was rapid and substantial in early post-glacial time (Fedje and Josenhans 2000, Lacourse and Mathewes 2005). In fact, Rolf Mathewes' use of the term 'Lost World' is quite appropriate for an ancient landscape where climate, vegetation communities, distribution of animal species, and even the nature and configuration of the physical landscape was quite unlike that of today (Fedje and Mathewes 2005; Koppel 2005). At 15,000 years ago there was an eighty-kilometer-wide grassy plain (Hecate Plain per Fladmark 1979) in the area of present-day Hecate Strait. By 10,700 years ago the plain was drowned and dense spruce-hemlock forests had risen to encompass all but the highest elevation areas of the archipelago (Fedje et al. 2005c).

Because ocean shorelines dating earlier than 10,700 years ago are drowned up to ca. 150 metres, we turned to investigation of karst landscapes as an alternative to the traditional focus on coastlines in the search for the early human record. Karst cave research elsewhere on the coast of southeast Alaska and British Columbia has also been successful in discovering late Pleistocene faunal remains (Heaton et al. 1996; Heaton and Grady 2003; Nagorsen and Keddie 2000; Nagorsen et al. 1995). Caves attract animals and people for food and for shelter and have the added benefit of good preservation of bone. We explored caves at elevations above the level of the early to mid-Holocene sea level maximum (15 m) as these could have an uninterrupted record extending back to the end of the last ice-age.

Here we discuss investigations conducted at three caves with reference to early post-glacial fauna and human occupation on this rapidly changing landscape. Previous work at the Kilgii Gwaay and Richardson Island archaeological sites carried the human and paleontological record for Haida Gwaii back to 10,700 years ago (Figure 1; Fedje et al. 2005 a, b). The karst cave record picks up at the Pleistocene-Holocene boundary (ca. 11,500 years ago) and extends back to at least 12,600 years ago for evidence of human activity and 13,400 years ago for paleontology. Recovery of 13,100-year-old dog remains further infers human presence to at least that time. All dates presented in this paper as years ago are calendrical, as calibrated from Stuiver et al. (2021). Delta R marine reservoir corrections follow Schmuck (2021).

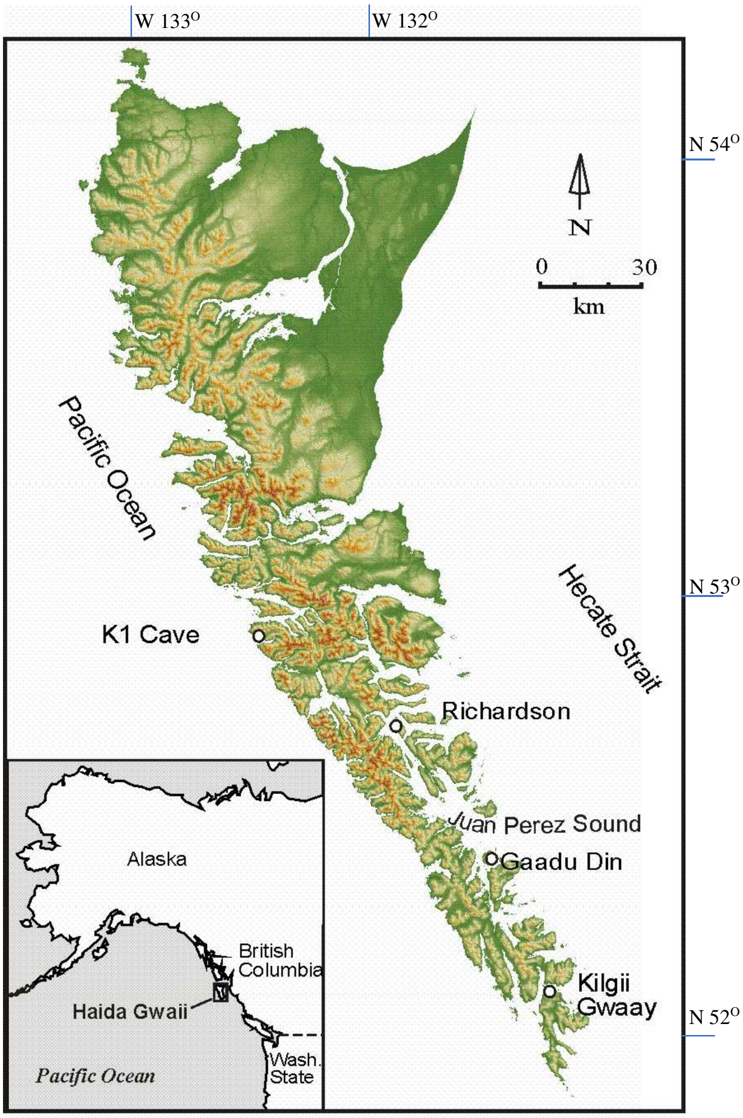


Figure 1 Study Area

Background

The Modern Fauna of Haida Gwaii

The historical terrestrial fauna of Haida Gwaii include many species of birds and fish, and a limited number of mammals. Mammals native to the archipelago are black bear (*Ursus americanus*), caribou (*Rangifer tarandus*, extirpated ca. 1910), marten (*Martes americana nesophila*), weasel (*Mustela erminea haidarum*), river otter (*Lontra canadensis*), deer mouse (*Peromyscus maniculatus* and *P. keeni*), shrew (*Sorex monticolus*) and four species of bats (*Myotis californicus, keenii, lucifugus* and *Lasionycteris noctivagans*) (Cowan 1989). Domestic dog (Canis familiaris) has been present on Haida Gwaii for at least five millennia (Wigen and Christensen 2001; Wigen 2005). In the last 200 years a number of species have been introduced, including deer, elk, beaver, raccoon, squirrels and rats.

The Archaeology of Haida Gwaii

Prior to the results of the work presented here, the archaeological record of Haida Gwaii was known to extend to at least 10,700 years ago (Fedje et al. 2005a). The period from the historic era to ca. 7,500 years ago is well documented from a number of sites throughout the archipelago (Fladmark 1979, 1989; Acheson 1998; Severs 1975; Christensen and Stafford 2005; Mackie and Acheson 2005). Only a few sites of early Holocene age (ca. 8,000 to 11,000 years ago) have been investigated (Fedje and Christensen 1999; Fedje et al. 2005a, b; Mackie and Sumpter 2005). The earliest of these, Kilgii Gwaay, dates to 10,700 years ago and exhibits abundant evidence of human occupation in association with extensive maritime fauna (Fedje et al. 2005a; Cohen 2014).

Three Caves

In this paper we present results from archaeological investigations carried out at three karst caves in the south of Haida Gwaii: K1, Gaadu Din 1 and Gaadu Din 2 (Figure 1). The record from these caves extends from the Bølling-Allerød to early Holocene times. Some preliminary results pertaining to the Younger Dryas portion of this record were previously published in a summary paper on BC archaeology and environments (Fedje et al. 2011a).

K1 Cave

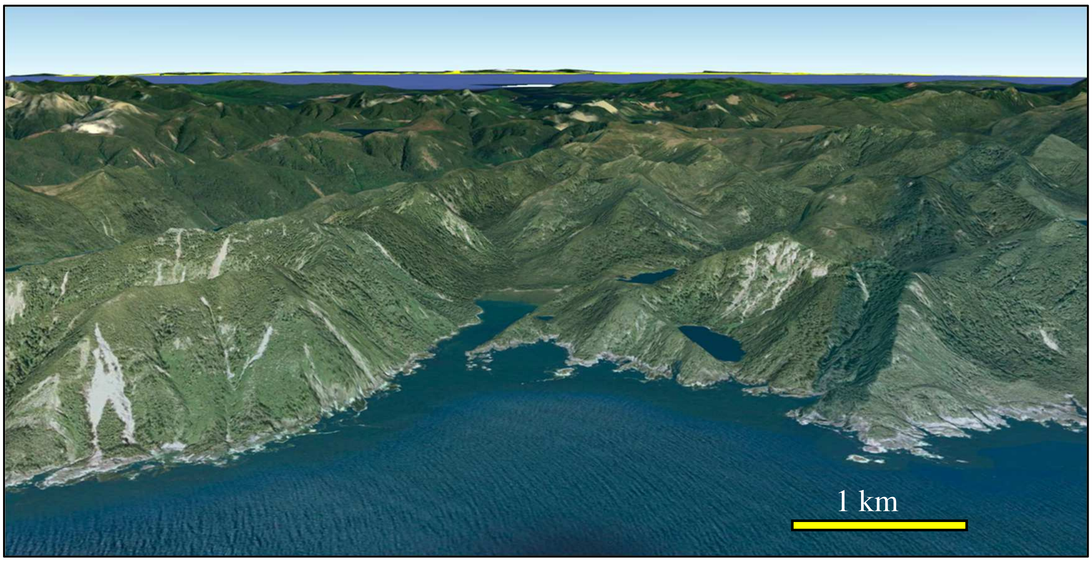
K1 Cave is located on the northwest coast of Moresby Island some 500 metres from the ocean shore and extends from ca. 10 to 50 metres above sea level (Figures 1, 2). The cave is a component of a karst system positioned in a small area of Sadler Formation limestone within an extensive area of Karmutsen Formation rock (Haggart 2001). K1 includes both active stream and inactive components. The main active system encompasses a large sinkhole that directs a small creek into a vadose passage that courses some 300 metres underground before exiting the system. There are a number of small sink-holes connecting to the underground creek by passages that are intermittently active. In addition, there are several fossil sections of vadose and phreatic passages that are inactive. At K1 Cave more than 1000 m of passages (including active, intermittent and fossil) have been surveyed (Figure 2b).

Investigative Background

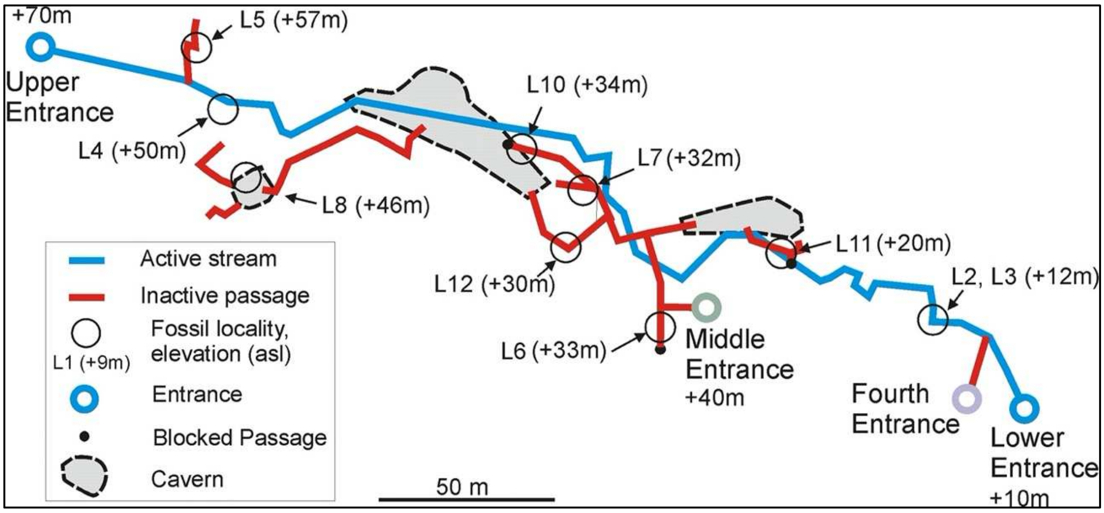
K1 Cave was subjected to exploratory investigations in 2000 and 2001. During this phase a small number of animal bones were collected from several localities within the system and formal mapping was initiated. Results of this preliminary work were reported on by Ramsey et al. (2004). In 2002 and 2003 site mapping continued and archaeological investigations were undertaken under British Columbia (BC) and Haida Nation permits (Fedje et al. 2004).

Fossil Localities and Surface Finds

Between 2000 and 2003 skeletal faunal remains were observed at 12 localities in K1 Cave. Loci 1 to 3 are in the active stream bed in the area of the lower entrance and Loci 4 through 12 are in inactive or intermittently active areas of the cave proper. Of note, fauna recovered from the non-archaeological work included a brown bear dated to ca. 17,200 years ago (Locus 7) and a dog dated to ca. 1740 years ago (Locus 6) (Ramsey et al. 2004). In this paper, we report on archaeological investigations at Locus 11.



a



b

Figure 2 K1 environs (from Google Earth 2020) (a); K1 Cave schematic plan (elevations are above mean sea level) (b)

Locus 11

K1 Locus 11 is a partially sediment filled fossil vadose passage in which a number of bones were found in eroding deposits (Figure 3, 4). The southerly end of the passage has been largely blocked by massive roof fall at the edge of the adjacent cavern. The exit at the north end of the Locus 11 passage is a vertical drop through a highly angular joint/passage to the underlying main active vadose passage. A fossil phreatic tube or low vadose passage extending east from Unit AA and AB (Figure 3b), is sediment filled to within 20 cm of its ceiling. The end of this passage is now blocked by debris, but was formerly an entrance to the cave system.

During a period of extremely heavy rainfall in 2001 a small rivulet ran through this passage and was actively eroding the fossil-bearing sediment. The narrow and steep-sided nature of the erosional channel suggests the erosion has not been of long duration. This apparent change

in fluvial dynamics may result from drainage blockage in the nearby (up-passage) chamber where there is evidence of recent rockfall.

Methods

Archaeological excavations at K1 cave were undertaken by a team of Parks Canada, Haida and University of Victoria archaeologists, and volunteers from the University of South Dakota between 2002 and 2003. Archaeological investigations focused on Locus 11 and included a total area of about 2.5 square metres (Figure 3b). Excavation was conducted in a combination of natural layers and 5 cm arbitrary levels. All sediment was water-screened using 3mm screens.

Results

This part of the cave produced a paleontological record dating from about 13,400 to 12,300 years ago and a small archaeological component dating to ca. 12,600 years ago.

Stratigraphy

Stratigraphy at Locus 11 is somewhat complex but can be divided into three main layers that exhibit distinct sedimentation (Figure 3c, d). The source of sediment at Locus 11 is a combination of roof-fall, alluvium and colluvium.

Layer 1 – Alluvial sand and fine gravel with occasional rounded clasts to cobble size.

This is the lowest sediment unit and was only encountered in excavation area A. It is alluvial sand and rounded gravel with occasional rounded clasts to cobble size. Clasts are predominantly igneous, derived from Karmutsen rock upstream from the cave system. The sand and fine gravel matrix suggest deposition by a relatively low energy stream as compared to the high energy modern day K1 Cave main streamway. Radiocarbon dating (Table 1) suggests this sediment unit was deposited ca. 13,300 years ago.

Layer 2 – Roof-fall residue with abundant clasts.

There is weak evidence of stratification in this layer. It is dominated by subangular limestone clasts and occasional chert nodules with interspaces filled by clay to fine sand-size matrix. The limestone clasts exhibit surface weathering but not water-rounding. The paucity of rock, other than limestone and minor chert, suggests most clasts are *in situ* roof-fall. The fine sediment exhibits limited evidence of sorting. Most of the matrix is silty clay, however some sandy silt strata are present. The fine sediments appear to derive from cave wall and roof weathering (insoluble residue in limestone) while the sandy silt layers reflect episodes of alluvial deposition. An *in-situ* source for these sediments (at least the coarser fraction) is inferred from bone distributions, including recovery of articulated bear foot elements, an articulated (non-fused) juvenile bear skull and bone refits between excavation units. These reveal an *in-situ* death or predator deposited assemblage. Radiocarbon dating (Table 1) suggests most of these sediments were deposited between 12,800 and 12,300 years ago.

Layer 3 – Alluvial silts and roof-fall clay residue with occasional clasts to pebble size.

This is the topmost layer. It is characterized by loose brown silty clay and occasional limestone clasts. There is recently deposited woody debris in the upper part of this layer as a result of intermittent ongoing low-energy stream action. The loose brown sediment appears to derive from three sources: *in situ* weathering, seepage through the easterly sediment cone and

fluvial deposition via the intermittent low-energy stream entering Locus 11 from the south through the main passage. The presence of preserved wood, and bone dating between 13,300 and 12,300 years ago, in this fluvial sediment suggests that much of this sediment was redeposited from recently eroded deposits (upstream of Locus 11).

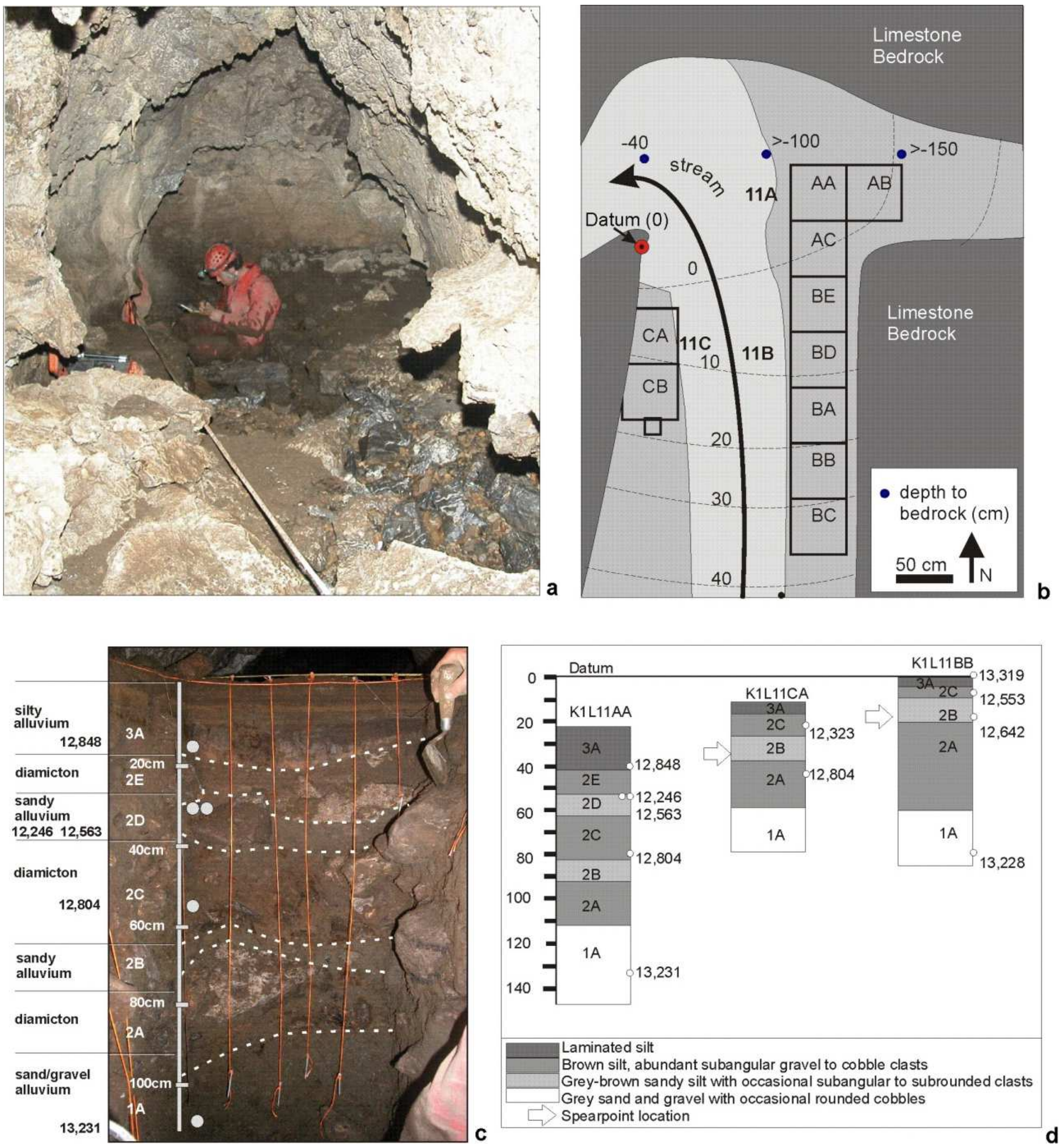


Figure 3 K1 Cave Locus 11: Duncan McLaren in view to north near K1L11C (a); plan of Locus 11 with 10 cm surface contours. The depth (below datum) to bedrock – blue dots - shows that the passage formerly continued to the east (b); profile of east wall Unit 11AB showing the depth from which dated bones were recovered (c); schematic stratigraphy excavation units 11AA, BB, CA (d). Ages are medians per Table 1.

Dating

Fourteen dates have been run on bone and one on charcoal (Table 1). The dates are stratigraphically consistent except for CAMS 93772 from Locus 11A which is ca. 300 to 500 years older than samples from 15 cm lower in Unit A. This specimen is from an alluvial layer near the top of the section and may have been redeposited from older strata by stream action. Similarly, three dates from surface collected bones appear to have been recently redeposited by the small stream. These include a bear and a caribou bone that date earlier than the underlying strata (Table 1).

Table 1 Radiocarbon dates for K1 Cave

K1 Cave	Sample	Depth below surface (dbs)	Material	D 13C	D 15N	14C age	% Marine	Cal yrs range (2 sd)	Median probability
Locus 11									
CAMS 79489	K1 S11-b	surface	Black bear	-20.2		11,250±70	12	13161-12841	13015
CAMS 79490	K1 S11-f	surface	Black bear	-21.1		10,450±60		12619-12056	12350
Locus 11A									
CAMS 93772	K1S11AA20	20	Black bear	-21.1		10,950±40		12987-12755	12848
CAMS 79687	K1 S11AA31	31	charcoal	-25		10,380±80		12607-11937	12246
CAMS 93773	K1S11AA30	30	Black bear	-20.4		10,640±60	17	12721-12198	12563
UCIAMS4882	K1L11AB6a	55	deer	-21.6	2.5	10,905±35		12890-12751	12804
CAMS 93776	K1S11AA3	54	Brown bear	-17.7		12,065±40	51	13581-13525	13363
UCIAMS4883	K1L11AB12	115	Brown bear	-16.8	7.5	12,070±40	64	13482-12992	13231
Locus 11B									
CIAMS75920	K1S11BB5	surface	Caribou	-17.5	3.0	11,445±45		13441-13184	13319
CAMS 93774 *	K1S11BB10	10	Black bear	-20.9		10,525±50		12691-12200	12553
CAMS 93775 *	K1S11BB20	20	Black bear	-20.5		10,660±40	7	12718-12491	12642
UCIAMS5732	K1L11BB80	80	Brown bear	-16.7	10.9	12,090±35	66	13482-12987	13228
Locus 11C									
UCIAMS4884 *	K1L11CB2a	15	Black bear	-19.9	1.0	10,510±35	17	12594-12062	12323
UCIAMS4886 *	K1L11CB3a	30	Black bear	-20.7	1.2	10,960±35	5	12892-12748	12804

* dates constraining age of the spearpoint bases

1) The quoted age is in radiocarbon years using the Libby half-life of 5568 years and following the conventions of Stuiver et al. (2020). Calendrical corrections are presented as 2 sigma calibrations using Calib 8.2 (Stuiver et al. 2021) with marine Delta R following Schmuck et al. (2021)(^{14}C >10,700 Delta R = 576, ^{14}C 10,700-10,000 Delta R = -55.62).

2) per cent marine carbon for bone with d13C heavier than -21 is calculated from sample 13C relative to collagen with a range of –21 (fully terrestrial) to –14.5 (fully marine).

3) d13C and d15N values for bone were measured to a precision of <0.1‰ on >10kD ultrafiltered collagen, using a Fisons NA1500NC elemental analyzer/ Finnegan Delta Plus stable isotope ratio mass spectrometer.

Paleontology

At Locus 11, a total of 1401 bones were collected (Table 2) of which 211 were identified to family or species (Fedje et al. 2004). Bear were most common (N = 156), with 69% identified as black bear, 16% as brown bear and 15% as bear only.

There are at least six individual black bears represented in the Locus 11 faunal assemblage including three adults and three juveniles. The actual number of black bears could be substantially higher. There are at least two brown bears, an adult and a subadult, represented by limb bones at different stages of development. Additionally, a deciduous canine and premolar suggest the presence of a much younger individual. Several of the brown bear elements compare well in size to the larger coastal brown bears. A single element, an innominate fragment, appears to have been chewed by a carnivore. It was not always possible to tell whether a bear bone was black or brown bear because both adults and juveniles overlap in size (e.g. the largest black bear males are similar in size to the smallest brown bear females).

Three bones are identified as caribou, one of which was dated to ca. 13,320 years ago. These bones fall within the size of modern woodland caribou (*Rangifer tarandus*), rather than the small Dawson's caribou (*R. dawsoni* or *R. tarandus dawsoni*), that was historically present on Haida Gwaii.

Six bones have been identified as deer. Deer have not been known from Haida Gwaii until their re-introduction ca. 1900 AD (Cowan 1989). A mandible fragment with teeth, was dated to ca. 12,800 years ago (Table 1). Size and age distribution on these elements indicate there are at least three individuals; one adult, a juvenile/subadult as indicated by an upper molar and deciduous premolar and a second adult indicated by a lower right molar 1. Several ungulate bones could not be assigned to either caribou or deer due to their condition. Most of these are similar in size to Vancouver Island deer (which are a small sub-species of blacktail deer).

In addition to these taxa, a single fish bone, a mouse and two sizes of songbirds were identified.

Table 2. K1 Cave Locus 11 Fauna – Number of Identifiable Specimens (NISP).

Brown bear	**25**	**Small songbird**	**2**
Black bear	**108**	**Medium songbird**	**1**
Bear sp.	**23**	**Unidentified bird**	**2**
Caribou	**3**	**Total bird**	**5**
Deer	**6**		
Ungulate	**22**	**Unidentified fish**	**1**
Large mammal	**18**	**Total fish**	**1**
Large land mammal	**5**		
Deer mouse	**2**		
Small rodent	**29**		
Small mammal/bird	**1**		
Unidentified mammal	**1153**		
Total mammal	**1395**	**Total Fauna**	**1401**

Taphonomy

Many of the bones from Locus 11 show trauma from carnivores, including tooth puncture and gouge marks, spiral fractures and crushing. Some of the bones (e.g., those recovered from the surface and from Layer 3) may have been transported from elsewhere in the cave system by colluvial or alluvial processes, however recovery of conjoinables and articulated specimens from Layer 1 and Layer 2 suggest these are *in situ*. They are likely from animals that were killed in the cave or brought in as prey. McLaren et al. (2005) cite evidence for predation on denning bears by other bears, and the introduction of food into caves by non-denning bears.

Archaeology

Two stone tools were recovered in association with black bear bones. These artifacts are the broken bases of large foliate spearpoints (Figure 4d, e). The points are somewhat different from early Holocene spear points previously known for Haida Gwaii in that the stems are broad and heavily ground. They compare well to points from early-stemmed point components in the Fraser Valley and in the U.S. northwest (McLaren 2017; Davis et al. 2012). The absence of butchering tools or waste flakes suggests these artifacts may have been brought in by wounded bears that

pulled them out in the safety of their den, or eventually died in this deep passage with the points still in their bodies.

The spearpoints were manufactured from chert that has a creamy-white to yellowish-brown surface colour. This material is unusual, and the source is not definitively known, however, massive chert beds are known to occur at Kitgoro Inlet and at Englefield Bay a few kilometers to the south of K1 (Hesthammer et al. 1991). These latter cherts are described as green in colour, weathering to yellowish with brown patches.

These artifacts appear to be of similar age though recovered several metres apart. The point base from Unit BB was recovered from a 10-cm level at 10 to 20 cm below surface. There are dates of ca. 12,553 above and 12,642 below the find layer, suggesting an age of ca. 12,600 years ago for this artifact. The point from Unit CB was from 20 to 30 cm below surface. There is a date of ca. 12,264 on bone from above the find layer and a date of 12,815 from immediately below. These results also suggest an age of at ca. 12,600 years ago for the artifact.

Figure 4 Brown bear mandible from Locus 11 (a); K1 Locus 11 brown bear vs. Mainland brown bear and modern Haida Gwaii black bear (b); Tim Heaton with point base (c); spearpoint bases from K1 Locus 11 (d, e).

Summary

Locus 11 at K1 cave appears to have been a lair and den, used by brown bear ca. 13,400 to 13,200 years ago and by black bear from ca. 12,850 to 12,300 years ago. The presence of ungulate remains, including some chewed by large carnivores, suggests the chamber was at times used as a lair. The paleontological and archaeological data suggests that this part of cave was not used by people. Rather, people likely hunted bear at the cave mouth and, occasionally, injured bears retreated to this chamber. The absence of the blade portion of spearpoints may be the result of the animals' pulling out the spear or foreshaft, with base still attached, while the point tip remained in their body.

Gaadu Din 1

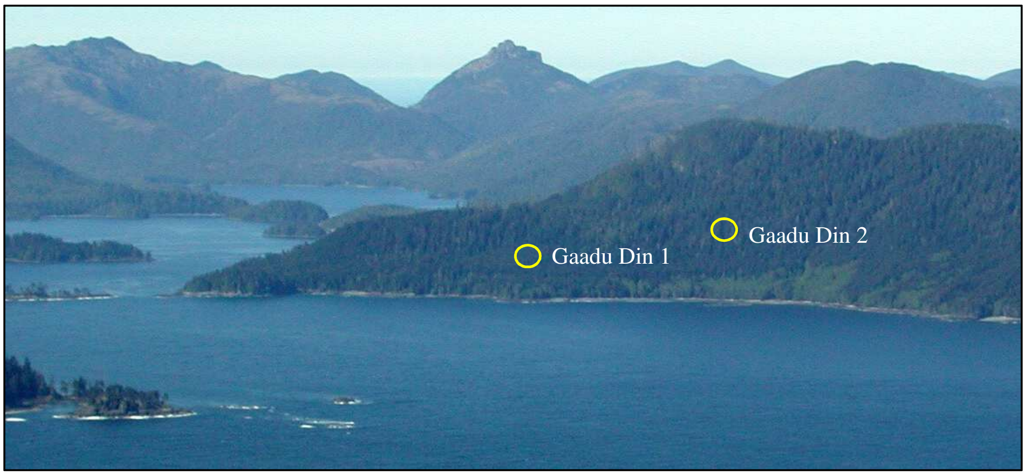
Gaadu Din 1 is a solution cave in Sadler formation limestone that is situated on the east side of Huxley Island some 200 metres from the ocean shore and ca. 30 to 50 metres above modern sea level (Figure 5a). The cave system includes three distinct levels including a dry upper level at 4 to 5 m above the cave datum (set at 50 m above sea level by karst system surveyor Paul Griffiths), an intermediate level with intermittent rivulet flow at +3 to –3 m, and a lower level at –5 to -13 m containing small streams. The largest passage is in the upper level. It exhibits relatively low gradient and is infilled with up to two metres of sediment. The lower levels exhibit steeper gradients with relatively little sediment and narrow, well-defined vadose incisions in the passage floors. Passages are relatively narrow and low, generally ranging from one to three metres wide. The Main Chamber is the most open and widens to 6 metres for a short distance (Figure 5b).

The age and timing of development of the Gaadu Din 1 cave system is incompletely known. The upper level is likely the oldest portion of the system based on paleokarst features such as phreatic tube remnants, fluvial gravel trapped in cave wall fissures and calcite-cemented to parts of the ceiling (suggesting that it was choked with gravel at one point) and a large stalagmite base that appears to have been broken during a high-energy fluvial part of the cave's development. These events occurred prior to the pre-14,000 years ago deposition of the lacustrine clay observed in the basal sediments (see below) and suggest development prior to the last glacial maximum.

The intermediate passage system appears to have been the main watercourse by 12,500 years ago based on dating of a black bear skull from under coarse alluvial sediment composed of exotic gravel and large water-rounded cobbles. Timing of the establishment of the current watercourse is not known. While the cave is presently 200 m from the ocean shore, this distance has varied greatly through time because of local relative sea level changes (Fedje et al. 2005c).

Methods

Archaeological excavations at Gaadu Din 1 cave were undertaken by a team of Parks Canada, Haida and University of Victoria archaeologists, and volunteers between 2003 and 2007. Archaeological investigations focused on the sediment-filled Main Chamber and included a total area of about eight square metres (Figures 5b, 6). Excavation was conducted in a combination of natural layers and 5 cm arbitrary levels. All sediment was taken out of the cave and water-screened through nested 6mm and 3mm screens.


Gaadu Din 1
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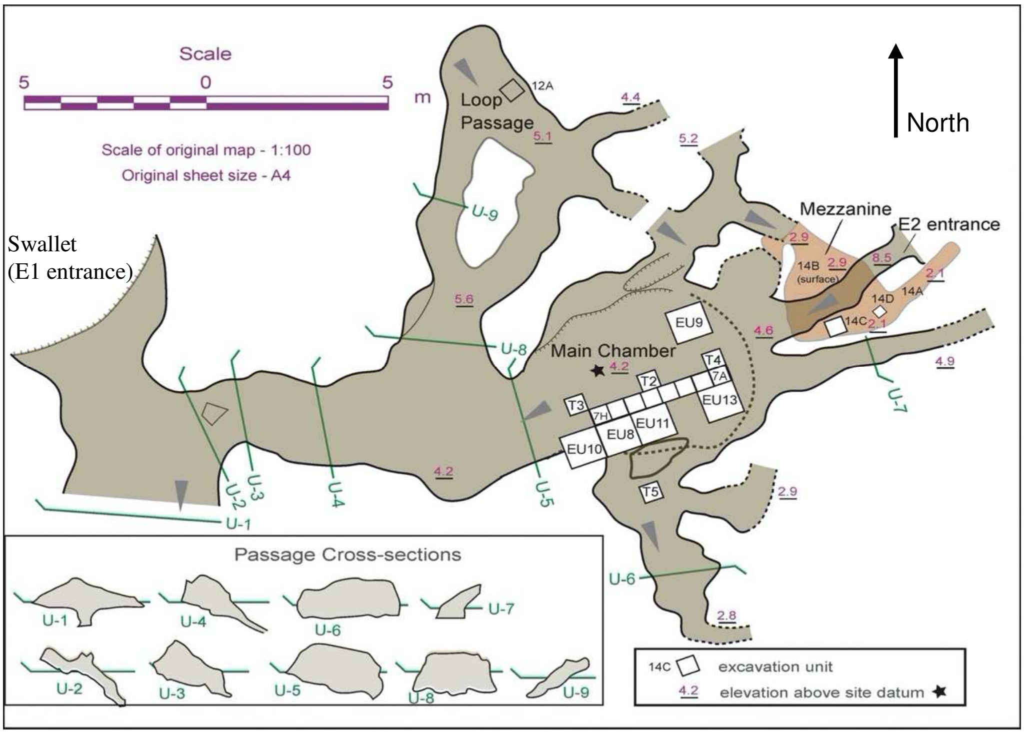
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North
Loop Passage
12A
Swallet (E1 entrance)
Mezzanine
E2 entrance
Main Chamber
14B (surface)
14A
14C
14D
EU9
EU8
EU10
EU11
EU13
T2
T3
T4
T5
7A
7H
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Passage Cross-sections
excavation unit
elevation above site datum
b

 c  d

Figure 5 Gaadu Din caves location (a); Gaadu Din 1 floor plan showing location of excavations (Map base and cross-sections extracted from karst system map prepared by Paul Griffiths)(b). Cave entrance from swallet (c). Excavating in Main Chamber (d).

Results

Results show that the cave site has an excellent paleontological record dating from about 13,400 to 11,300 years ago and a small, but significant, archaeological component. Data presented here are from the Main Chamber.

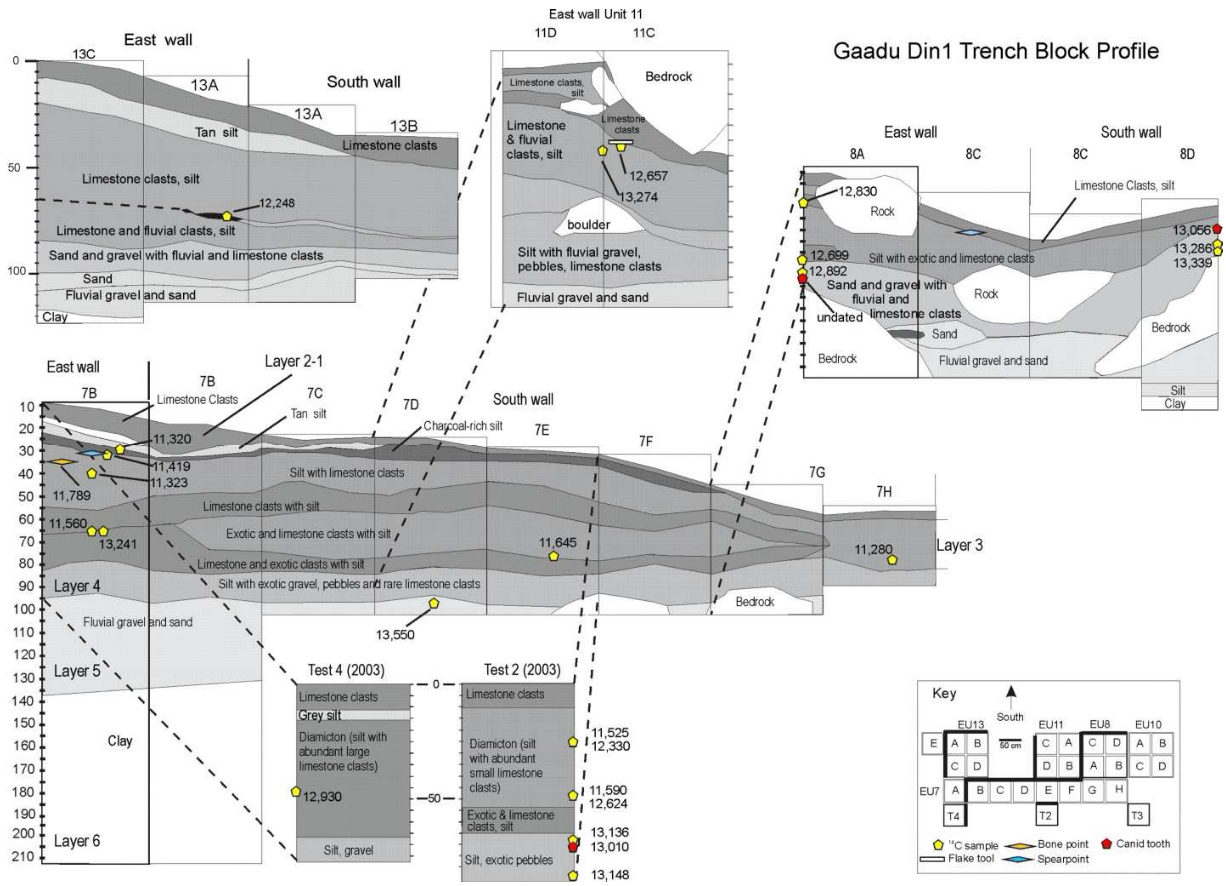


Figure 6. Gaadu Din 1 South Block (contiguous excavation units on south side of the main chamber) stratigraphy. Dates are median calendar ages per Table 3.

Stratigraphy

Stratigraphy in the area of the Main Chamber at Gaadu Din 1 can be divided into six layers that exhibit distinct sedimentation (Figure 6). Sediment source appears to include a combination of roof-fall, limestone residue, *in situ* deposited organics, alluvium and colluvium. There is relatively good stratigraphic separation of these layers in the east part of the South Block as a result of multiple roof fall events between 13,000 and 11,500 years ago. These events may reflect greater humidity and temperature fluctuations in proximity to the cave entrance. There appears to be very little post-13,000 years ago sediment towards the west end of the cavern and this has resulted in compressed stratigraphy. This area includes a few limestone boulders (roof-fall) but does not contain the angular limestone cobble layers seen at the east end. This may relate to more constant temperatures away from the entrance. The east end of the South Block is adjacent to a debris cone and there are abundant angular limestone clasts on the surface. In this area, there are no speleothems and the limestone ceiling exhibits masses of frostwork (aragonite crystals formed by moist circulating air containing calcium carbonate) up to 10 cm thick. At the west end of the South Block there are no angular clasts on the surface, frostwork is absent, and speleothems are present.

The oldest sediment observed in the Gaadu Din 1 cavern comprises sub-angular to rounded alluvial sand, gravel and pebbles calcite-cemented to the cavern roof and walls (and thus

not shown in profile). These sediments would have become adhered to the roof during an early vadose phase of cave development, possibly before the last glacial maximum, when alluvium nearly filled the cavern.

Layer 6 – Glaciolacustrine clay

Basal sediments encountered in excavations are glaciolacustrine clays (Edana Fedje written comm. 2005) indicating that the cave system was flooded, during or immediately following the glacial maximum, by an ice-dammed proglacial lake or by subglacial ponding (cf. Al-Suwaidi et al. 2006, Larsen et al. 1987, Gunn 2006). Striae exposed on bedrock on the south shore of Huxley Island show that a glacier flowed northerly along the east side of the island (Sutherland Brown 1968). The Huxley evidence is similar to that at nearby Arrow Creek where glaciolacustrine clays, containing freshwater diatoms and rare plant fossils, are exposed at the base of the creek some 5 m above present sea level. These clays are dated to ca. 14,400 years ago (Fedje, unpublished data: CAMS 14439, willow leaf, 12,300±140). The apparent absence of microfossils at Gaadu Din 1 implies that the clay there may have been deposited at an earlier stage of deglaciation than at Arrow Creek.

Layer 5 - Alluvium

The rounded alluvium and grey silts and sands (Layer 5) incised into and overlying the glaciolacustrine clay are associated with the early post-glacial vadose history of the cave system. They appear to date earlier than 13,400 years ago.

Layer 3, 4 - Diamicton

The overlying sediments (Layers 4 - 3) can best be described as diamicton although some stratification is evident and most radiocarbon dates are, except in EU9, in stratigraphic order. Much of the thick, clast-rich sediment was deposited during the time of the Younger Dryas cold interval, which is dated on the coast to ca.12,900 to 11,700 years ago (Menounos et al. 2009, 2017). Roof-fall clasts are most abundant in that area of the cavern closest to the entrance. The rapid breakdown of limestone evident near the cave entrance at Gaadu Din 1 is consistent with geological studies showing that spalling and weathering increase markedly during periods of cold moist conditions, especially during freeze-thaw cycles (Larsen et al. 1987; Farrand 2000).

Layer 1, 2 – Alluvium and limestone residue

The uppermost few centimetres of sediment (Layers 2 – 1) in the cavern was deposited over the subsequent 11 millennia and imply more moderate environmental conditions. The apparent absence of Holocene mammal remains suggests that the E2 entrance may have been largely blocked by 11,000 years ago (when located in 2003 the entrance opening was ca. 10 cm in diameter).

Dating

Forty-three dates have been run on bone and charcoal from the Main Chamber area. The bone dates are on bear, deer, unspeciated ungulate, canids and salmon. The dates indicate use of the cave by animals between 13,400 and 11,200 years ago. These results (Table 3 below) support a temporally consistent stratigraphic record for most of the deposits. Inverted dates from units at the east end of the chamber may be the result of older material being redeposited by colluvial action at the steep entrance. This was likely exacerbated by animals entering and exiting the cavern. Both EU9 and the east end of EU7/13 are at the toe of the steep slope up to the cave entrance and our transits of the narrow entrance resulted in more than 20 cm of material being redeposited at the base of the slope in ten days. There likely has been some mixing of sediment by bears in Layers 3 and 4 throughout the chamber. In the southeast corner of EU8, for example,

there is a concentration of bone, including several of brown bear, that has been pushed up against the bedrock face, likely by bears cleaning up a denning area. Several long bones are obliquely positioned, some extending to near the surface, and there is an abundance of complete bones. Dates on charcoal associated with stone tools indicate the cave was likely intermittently used by people between 12,700 and 12,200 years ago.

Table 3. Radiocarbon Dates from Gaadu Din 1 Cave

Location, lab#	Sample	Material	D ^{13}C	D ^{15}N	^{14}C age	**% Marine**	**Cal years BP Range (2 sd)**	**Cal years median probability**
GD1-EU2								
UCIAMS5750	EU 2A4	Salmon	-14.8	15.0	10,955±35	92	12030-11088	11525
UCIAMS5753	EU 2A4	Black bear	-20.3	-1.1	10,485±35	11	12596-12100	12330
UCIAMS5754	EU2A7	Salmon	-15.4	15.6	10,935±35	86	12084-11164	11580
UCIAMS5755	EU2A7	Black bear	-21.3	2.7	10,575±35		12695-12487	12624
UCIAMS15151	EU2A11	Canid	-15.6	18.8	12,070±30	83	13298-12734	13010
UCIAMS23610	EU2A11	Ungulate	-19.6	1.3	11,230±35		13175-13092	13136
UCIAMS4888	EU2A15	Brown bear	-16.3	12.1	12,205±40	83	13455-12828	13148
GD1-EU4								
UCIAMS4892	EU4A6	Deer	-20.7	2.2	11,005±45		13079-12822	12930
GD1-EU5								
UCIAMS4889	EU5A2	Black bear	-21.7	2.3	10,585±45		12711-12486	12630
UCIAMS5733	EU5A2	Black bear	-21.5	2.4	10,550±35		12683-12481	12577
UCIAMS4890	EU5A7	Brown bear	-17.0	9.5	11,985±50	62	13424-12908	13172
GD1-EU7								
UCIAMS23611	EU7A7	Deer	-21.6	4.4	10,965±40		13054-12759	12868
UCIAMS23612	EU7A7	Brown bear	-16.4	16.3	12,025±40	71	13372-12816	13108
UCIAMS23613	EU7A11	Ungulate	-21.7	2.3	11,265±35		13236-13096	13149
UCIAMS12387	EU7B2a	Charcoal	-32.2	--	9,930±30		11600-11242	11320
UCIAMS12386	EU7B2b	Charcoal	-27.7	--	9,980±30		11682-11269	11419
UCIAMS15156	EU7B6	Brown bear	-15.6	16.4	10,715±30	83	11788-10872	11323
UCIAMS31729	EU7B7	Bone point	-21.8	1.6	10,150±25		11931-11648	11789
UCIAMS23614	EU7B13	Salmon	-15.5	--	10,910±40	85	12041-11152	11560
UCIAMS23615	EU7B13	Brown bear	-15.6	12.6	12,320±40	85	13572-12917	13241
UCIAMS15153	EU7D16	Brown bear	-17.5	10.8	12,085±30	54	13578-13129	13350
UCIAMS15164	EU7E11	Salmon	-15.5	14.6	10,970±25	85	12126-11204	11645
UCIAMS15165	EU7H7	Salmon	-14.7	15.7	10,830±35	97	11791-10762	11280
GD1-EU8								
UCIAMS15159	EU8A2	Deer	-21.4	3.4	10,935±40		12956-12752	12830
UCIAMS15162	EU8A9	Deer	-22.1	6.0	10,990±25		13061-12826	12892
UCIAMS15163	EU8A10	Salmon	-16.6	13.8	11,510±25	68	12936-12417	12669
UCIAMS23620	EU8B4	Brown bear	-15.6	12.6	12,355±45	85	13559-12937	13275
UCIAMS21995	EU8D2	Dog	-15.5	18.7	12,140±35	85	13350-12746	13056
UCIAMS23616	EU8D5	Brown bear	-16.6	10.2	12,230±40	68	13593-13094	13339
UCIAMS23621	EU8D5	Brown bear	-16.6	10.2	12,175±40	68	13576-13056	13286
GD1-EU9				--				
UCIAMS15161	EU9B3	Deer	-22.4	6.1	10,920±35		12894-12755	12813
UCIAMS15152	EU9A7	Brown bear	-16.7	10.9	12,230±30	66	13579-13112	13360
UCIAMS12388	EU9C8	Charcoal	-27.2	--	10,550±25		12675-12485	12540
UCIAMS15160	EU9B12	Deer	-24.3	--	11,060±30		13086-12902	12998
UCIAMS15157	EU9C14	Black bear	-20.8	4.3	11,500±30	3	13445-13246	13343
UCIAMS15154	EU9A17	Black bear	-20.2	3.8	11,030±30	15	12896-12750	12810
GD1-EU11								
UCIAMS28004	EU11D#1	Bone	-19.5	6.4	11,665±30	23	13410-13167	13274
UCIAMS28005	EU11D#2	Charcoal		--	10,615±30		12714-12502	12657
GD1-EU12								
UCIAMS33981	EU12A8	Bone	-20.7	-0.7	10,490±35	4	12619-12195	12493
GD1-EU13								
UCIAMS41044	EU13E3	Brown bear	-15.9	14.0	12,335±35	78	13648-13059	13333
UCIAMS41042	EU13A5	Brown bear	-16.1	15.0	10,660±30	75	12460-11997	12102
UCIAMS41043	EU13E6	Brown bear	-16.5	14.2	10,465±30	69	12144-11408	11807
UCIAMS28006	EU13A10	Charcoal		--	10,370±30		12470-12004	12248

1) The quoted age is in radiocarbon years using the Libby half-life of 5568 years and following the conventions of Stuiver et al. (2020). Calendrical corrections are presented as 2 sigma calibrations using Calib 8.2 (Stuiver et al. 2021) with marine Delta R following Schmuck et al. (2021)(^{14}C >10,700 Delta R = 576, ^{14}C 10,700-10,000 Delta R = -55.62).
2) per cent marine carbon for bone with d13C heavier than -21 is calculated from sample 13C relative to collagen with a range of –21 (fully terrestrial) to –14.5 (fully marine).
3) d13C and d15N values for bone were measured to a precision of <0.1‰ on >10kD ultrafiltered collagen, using a Fisons NA1500NC elemental analyzer/ Finnegan Delta Plus stable isotope ratio mass spectrometer.

Paleontology

For this paper, only the fauna from contiguous excavations in the Main Chamber (Gaadu Din South Block - Figure 5b) are included. The Gaadu Din 1 mammal bones include black and brown bear, blacktail deer, domestic dog, a medium-sized canid, mouse, bat and shrew. Table 4 provides counts for all taxa by layer. Overall, the mammals are dominated by bear (560) of which 369 are black bear and 96 are brown bear, and by ungulates (21) of which 9 are deer. Black bear bones are present on the cavern floor (undated) and in all but the lowermost levels with specimens dated from ca. 13,300 to 12,300 years ago. Brown bear date from ca. 13,400 to 11,300 years ago. None were present on the cave floor surface. Ungulates exhibited limited temporal representation with five dated specimens ranging from 13,100 to 12,800 years ago. Fish are dominated by salmon with over 2000 salmon bones recovered from Main Chamber excavations. Five of these were dated, pointing to an age range ca. 12,700 to 11,300 years ago. Birds are dominated by Ancient murrelets (which often nest in caves and rock crevices) and songbirds.

Table 4 Gaadu Din 1 Fauna by Layer

Taxa Layer	1	1-2	2	3	4	5	unnasigned	Grand Total
BIRD	**7**	**55**	**2**	**44**	**1**		**20**	**129**
Alcid (sm)				1				1
Ancient murrelet		23	1	7			7	38
Duck				1				1
Duck (med)				1				1
Grebe sp. (lg)							1	1
Large songbird				1				1
Medium songbird		8		7				15
Small songbird		3		4			1	8
Very small songbird		1						1
Pelagic cormorant				1				1
Unidentified bird	2	11	1	8			11	33
Unidentified bird (med)				1	1			2
Unidentified bird (sm)	5	9		12				26
CRABS	**6**	**4**	**2**	**3**			**3**	**18**
Crab, undet.	6	4	2	3			3	18
FISH	**118**	**665**	**324**	**3143**	**150**	**12**	**123**	**4535**
Antlered sculpin				1				1
Black prickleback			1					1
Buffalo sculpin				1				1
Dolly varden			1	19				20
Flatfish sp		1			1			2
Great sculpin				2				2
Greenling sp		2		5				7
Gunnel sp.				1				1
Gunnel/Prickleback			1	1				2
Irish lord sp		2		2		1		5
Lingcod		1						1
Pacific herring		1		1				2
Red Irish lord		1						1
Rockfish sp		3		5				8
Sablefish		1						1
Salmon	30	156	102	1292	38	4	54	1676
Salmon/Trout	1		3	3				7
Sculpin sp		3						3
Staghorn sculpin			1					1

Steelhead trout				9				9
Unidentifiable fish	87	494	215	1801	111	7	69	2784
GASTROPODS	**1**			**2**			**1**	**4**
Checkered Periwinkle				1			1	2
Red Turban	1							1
Sitka Periwinkle				1				1
LAND SNAIL	**1**	**1**		**4**			**3**	**9**
Land Snail	1			2			3	6
Pacific Bananaslug				2				2
Robust Lancetooth		1						1
MAMM/BIRD	**3**	**25**	**1**	**7**	**2**			**38**
Small mammal\bird	3	25	1	7	2			38
MAMMAL	**86**	**394**	**183**	**3295**	**508**	**37**	**590**	**5093**
Bat sp.	2					1		3
Bear sp. (undet.)	1	6	1	60	19	3	5	95
Black bear	8	43	15	239	31		33	369
Brown bear		9		40	26	9	12	96
Canid				2	1			3
Carnivore sp.	1				1			2
Carnivore sp. (lg)		2	1					3
Deer mouse	1	2		9			5	17
Domestic dog		1						1
Fisher				1				1
Blacktail deer		1	1	3			4	9
Rodent (sm)	2	8	1	19	1		2	33
Sea otter?				1				1
Shrew sp.				1				1
Undet.land mammal (lg)				3	1		3	7
Undet.mammal	70	302	161	2764	398	17	511	4223
Undet.mammal (lg)	1	20	2	123	27	7	15	195
Undet.mammal (sm)				22				22
Ungulate (med)				1	2			3
Ungulate sp.			1	7	1			9
Grand Total	**222**	**1144**	**512**	**6498**	**661**	**49**	**740**	**9826**

Taphonomy

Most of the bone recovered from the Main Chamber at Gaadu Din 1 shows evidence of processing by carnivores. Over 95 per cent of the medium to large mammal bones have a maximum dimension of less than 5 cm. Complete bones are largely limited to teeth and metapodials. In most cases, even robust large mammal bones such as brown bear limb bones have been reduced to small splinters or heavily gnawed fragments. Carnivore agency is supported by recovery of many bear canines with evidence of pressure spalling and by the large proportion of bone fragments with punctures and gouging from large canine teeth. Small patches of crushed, chewed and acid-etched (cf. stomach acid) bone, some of which can be refit, are likely the remains of carnivore coprolites. These data suggest the cave was used by large carnivores (e.g., brown bear) for predation on other bears or for eating of animals brought in from open-air kill or scavenging sites. Fragmentation and bone size allow the possibility that some of the bone arrived in the gut of a large carnivore rather than being processed in the cave.

Overall, the black bear element frequencies approximate expected values for a complete bear, suggesting they died in the cave. The high degree of post-mortem bone trauma suggests most were killed and eaten by a large carnivore (most likely brown bear). This suggests predation of denning bears (Smith and Follmann 1993; Ross et al. 1988; Tietje et al. 1986). Unlike black bears and small brown bears, large brown bears (many of the bear bones from Gaadu Din 1 are from very large brown bears) require meat to meet their nutritional needs (Rode et al. 2001).

Brown bear is the only species present for which a significant number of unmodified bones are present (excluding teeth, hyoids and foot bones). Fifteen per cent of these brown bear bones are complete as compared to only five per cent for black bear. This may support some use of the cave for denning by brown bear. Most brown bear bones were recovered from a possible

denning area in the environs of Unit 8. The brown bear elements are approximately as expected except for a near absence of long bones (Table 5). This may indicate removal of choice parts (limbs excluding feet) by humans; however, an alternate explanation may be that large bones were pushed to the side of the cave during den or lair preparation and, thus beyond the bounds of our excavations. These frequencies are quite distinct from those seen at the 10,700 years ago open air Kilgii Gwaay archaeological site where black bear long bones and skulls were abundant but vertebrae and foot bones virtually absent. The latter pattern suggests that at Kilgii Gwaay, interpreted as a summertime base camp, skulls and choice elements were brought to the site by humans (Wigen 2003; McLaren et al. 2005).

Table 4 Bear bone frequency (selected element groups): Gaadu Din 1 (GD), Kilgii Gwaay (KG), expected (from McLaren et al. 2005)

ELEMENT	GD Black bear		GD Brown bear		KG black bear		Bear expected	
(general)	NISP	%	NISP	%	NISP	%	NISP	%
Teeth	63	25.2	23	31.5	78	60.1	38	16.0
Long bones	23	9.2	4	5.5	33	25.6	14	5.9
Vertebrae	34	13.6	14	19.2	5	2.3	36	15.1
Foot bones	130	52.0	32	43.8	13	10.1	150	63.0
Total	250		73		129		238	

Typically bears tend not to eat or drink when denning (Hellgren 1995; Mills 1919). As a result, the Gaadu Din 1 data suggest this part of the cave was primarily used by brown bears as a kill site (preying on black bear occupants) and foraging station. To a lesser extent it was used as a den site for one or both species. There remains the possibility that other large carnivores (e.g., wolves, foxes, large cats, short-face bear) played a role in production of the Gaadu Din 1 faunal assemblage, however, there is, as yet, no evidence for such animals having ever been present on Haida Gwaii.

Birds present include ancient murrelet, cormorant, unspeciated alcids and songbirds in the upper levels (<11,500 years ago) and songbirds and a duck in the lower levels. The absence of marine birds in the lower levels is consistent with landscape reconstruction that indicates the ocean shore was several kilometers distant prior to 12,500 years ago.

Fish include a variety of small marine species and salmonids in the upper levels and only salmonids in middle and lower levels. Most of the salmon bones are well preserved, with many vertebrae having large spines still attached, rather than being chewed up as would be expected from smaller carnivores.

Table 5 Gaadu Din 1 Salmonids: Body Part (NISP) by Layer

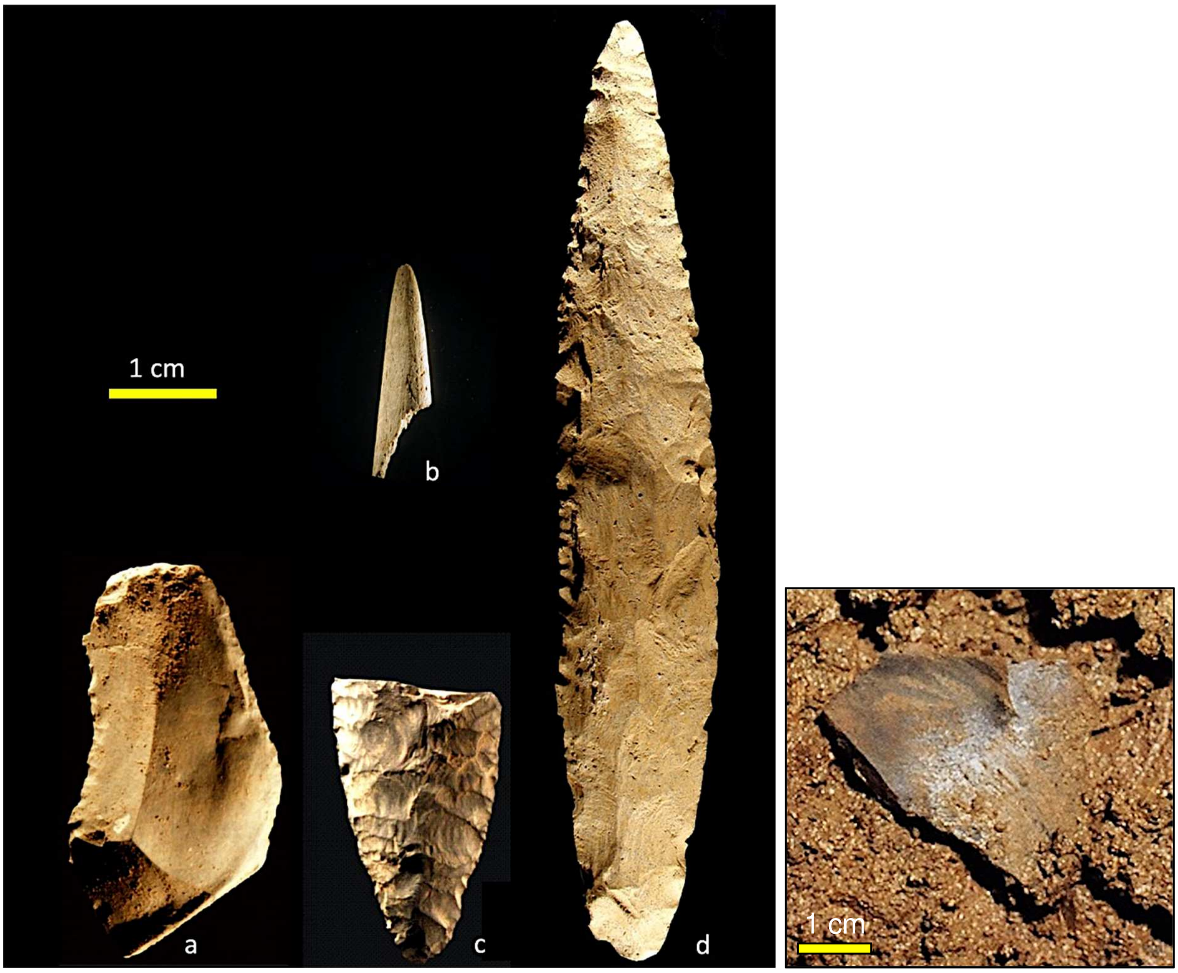
	Layer stratified										
Body Area	**1**	**2**	**02-3a**	**02-3c**	**03a**	**03b**	**03c**	**03c-d**	**03d**	**4**	**5**	**Total**
Head bones	28	26	4	20	134	9	25	1	5			**252**
Cranial %	*14*	*14*	*15*	*16*	*14*	*13*	*12*	*13*	*13*	*0*	*0*	***14***
Pectoral girdle	2			2	9		1					**14**
Pelvic girdle	3	1		1	8		2					**15**
Vertebral column	156	138	22	93	718	58	160	7	34	20	2	**1408**
Tail assemblage	12	19		8	78	1	13		1	2	1	**135**

Post-cranial %	*86*	*86*	*85*	*84*	*14*	*87*	*88*	*87*	*87*	*100*	*100*	***86***
Total	**201**	**184**	**26**	**124**	**947**	**68**	**201**	**8**	**40**	**22**	**3**	**1822**

Archaeology

The evidence for people at Gaadu Din 1 is relatively limited. Artifacts recovered include two stone spearpoints, the tip of a bone point and two stone flake tools (Figure 7a-e). A nearly complete spearpoint was recovered immediately below a date of 11,400 years ago on charcoal (Table 3). The bone point was directly dated to 11,790 years ago. A date of 12,540 years ago was obtained on charcoal associated with a large flake in EU9. A date of 12,660 years ago was obtained from charcoal associated with a stone tool from EU11.

Stratigraphy, dating and the distribution of faunal material (clusters and conjoinables) gives good confidence in the EU7 and EU11 artifact associations, however the EU9 charcoal date – artifact association is less secure because of evidence for sediment redeposition. Charcoal was relatively abundant in the cave sediment but generally fairly scattered with only one concentration, in EU13, possibly representing part of an ancient campfire. The latter is a semi-circular basin-shaped lens of charcoal-rich sediment dating to 12,250 years ago.



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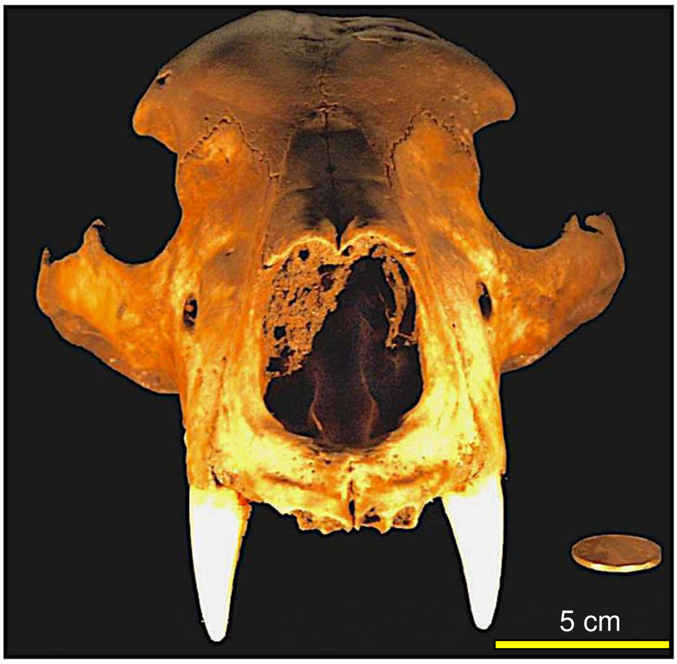

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Figure 7 Artifacts and select bones from Gaadu Din 1 excavations. Flake tool (a), tip of bone point (b), spearpoints (c, d), flake tool *in situ* (e), brown bear skull (f), three canid and three ungulate teeth (g).

Artifact Descriptions

1693T9C8-1 Unmodified flake exhibiting nibbling use-wear (Figure 7e). One lateral edge exhibits abrupt unifacial microflaking on the dorsal surface only, suggesting use-wear from light scraping activity, while the opposite edge exhibits acute bifacial microflaking, suggesting use-wear from cutting activity. This tool was associated with charcoal dating to 12,540 years ago, however, it's position at the base of the steep entrance tunnel and evidence for sediment redeposition in overlying layers reduces confidence in this date.
Material: Black siliceous argillite.
Dimensions: Length 39 mm Width 50 mm Thickness 9 mm

1693T11DT3-1 Retouched Levallois-like flake (Figure 7a). Both lateral edges exhibit abrupt retouch on the dorsal surface. The tool was associated with charcoal dating to ca. 12,660 years ago.
Material: Black siliceous argillite.
Dimensions: Length 72 mm Width 40 mm Thickness 10 mm

1693T7B7-1 Tip of bone point with longitudinal grinding that has produced slightly faceted edges (Figure 7b).
Material: Land mammal bone. The bone dates to 11,790 years ago.
Dimensions: Length 24 mm Width 6 mm Thickness 4 mm

1693T8C2-1 Foliate spearpoint basal fragment (Figure 7c) exhibiting collateral billet flake scars and a thin (6 – 7 mm) lenticular cross-section. The base is fairly broad (~6 mm), and has

been formed by abrupt retouch. Patchy light grinding is evident on the upper part of one lateral margin. See Fedje et al. (2008) for a more detailed description.
Material: Black siliceous argillite.
Dimensions: Total length 50 mm; stem length: 46 mm; maximum stem width: 30 mm; stem thickness: 7.5 mm
This specimen was recovered from the upper part of Stratum 3 which dates from 13,000 to 11,500 years ago

1693T7B5-1 Large foliate spearpoint (Figure 7d) exhibiting collateral billet flake scars on the stem portion and lamellar flake scars on the blade. The stem is relatively thin (8 – 9 mm) and lenticular in cross-section while the blade is thick (11 – 12 mm) and lenticular to diamond-shaped. One corner of the base is broken while the other exhibits a finely flaked rounded corner. The planar base is fairly broad (~5mm) and unmodified. The lower lateral margins exhibit light grinding. See Fedje et al. (2008) for a more detailed description. The point immediately underlies a charcoal date of 11,400 years ago.
Material: Yellow-brown patinated argillite.
Dimensions: Total length 155 mm; Stem length: 50 mm, Maximum stem width: 29 mm
Maximum blade width: 27 mm Stem thickness: 9 mm, Maximum blade thickness: 12 mm

Summary

Investigation at Gaadu Din 1 suggests the cave was used as a den by black bear from ca. 13,300 to 12,300 years ago, and as a den, lair or hunting site by brown bear from ca. 13,400 to 11,300 years ago. The complete and fragmentary stone and bone projectile points were likely deposited in the cave by wounded bears when pulling out the point foreshafts or dying in the cave. The presence of a few simple stone knives suggest people were occasionally in the cave butchering some of these animals. Along with scattered charcoal and dog remains, the hunting-butchery evidence suggests that people were hunting bear at the cave mouth (cf. Hallowell 1926; McLaren et al. 2005). A hearth feature near the cave entrance raises the possibility of brief use of the chamber by people around 11,400 years ago.

Gaadu Din 2

Gaadu Din 2 Cave is a small solution cave, in Sadler formation limestone. It is situated ca. 100 metres above modern sea level on the east side of Huxley Island and is approximately 200 metres from the ocean shore (Figure 5a). The Gaadu Din 2 cave system includes about 60 metres of accessible passages (Figures 8a). The cave entrance became exposed in 2006 as a result of a tree blowing down. The tree roots pulled out forest soils and a cluster of large limestone clasts exposing a ca. three metre square area of limestone bedrock and the cave entrance (Figure 8c). The cave, which exhibits little evidence of speleothem development, includes both active and inactive passages. The Front Passage (Figure 9a, b) exhibits no evidence of recent alluvial activity. Charcoal from within a few centimetres of the surface in this area dates to over 12,000 years ago (Table 6). Intermittent streams at the back of the cave system course through passages (A, B, C) that narrow and become impassable. A low bedrock sill separates the active and inactive passages (Figure 8b).

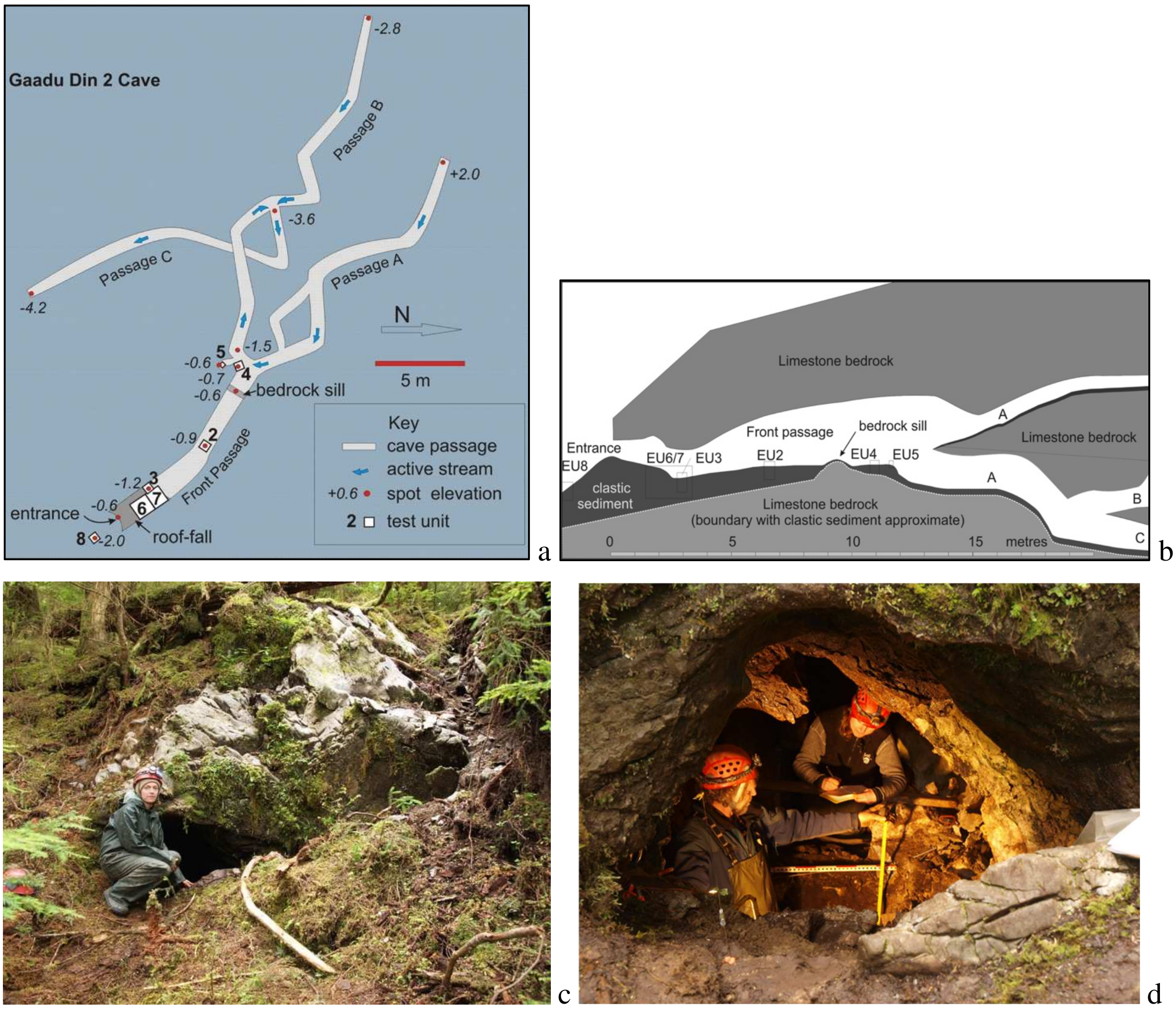


Figure 8 Gaadu Din 2 plan (a) and profile (b) schematics; cave entrance exposed by windthrown tree (c), excavation in progress (d).

Method

In 2007, preliminary examination of the cave included photo-documentation, surface collection (1 artifact), and excavation of four 25 cm square tests to a maximum of 50 cm depth. The 2008 investigations included excavation of a 1.0 by 1.8 m unit (1906T6/7) at the cave entrance (Figures 8, 9) and a 25 cm square test two metres in front of the entrance (1906T8). Excavation was conducted in 5 cm levels and all sediment was water screened through nested 6 mm and 3 mm mesh screens.

Results

A radiocarbon date of 11,890 years ago was obtained from charcoal immediately underlying a surface exposed spearpoint in the Front Passage (Test Unit 2). A stone knife that had been partially exposed by a water drip was excavated as part of Test Unit 4. Charcoal associated with the biface dated to 12,020 years ago indicating the sediment is contemporary with that of the Front Passage. These data, and sediment character as described below, suggest that low-energy

alluvial sediment overtopped the bedrock sill earlier than 12,020 years ago. Subsequent to that time stream action was largely confined to the extant stream channel (Passages A – C).

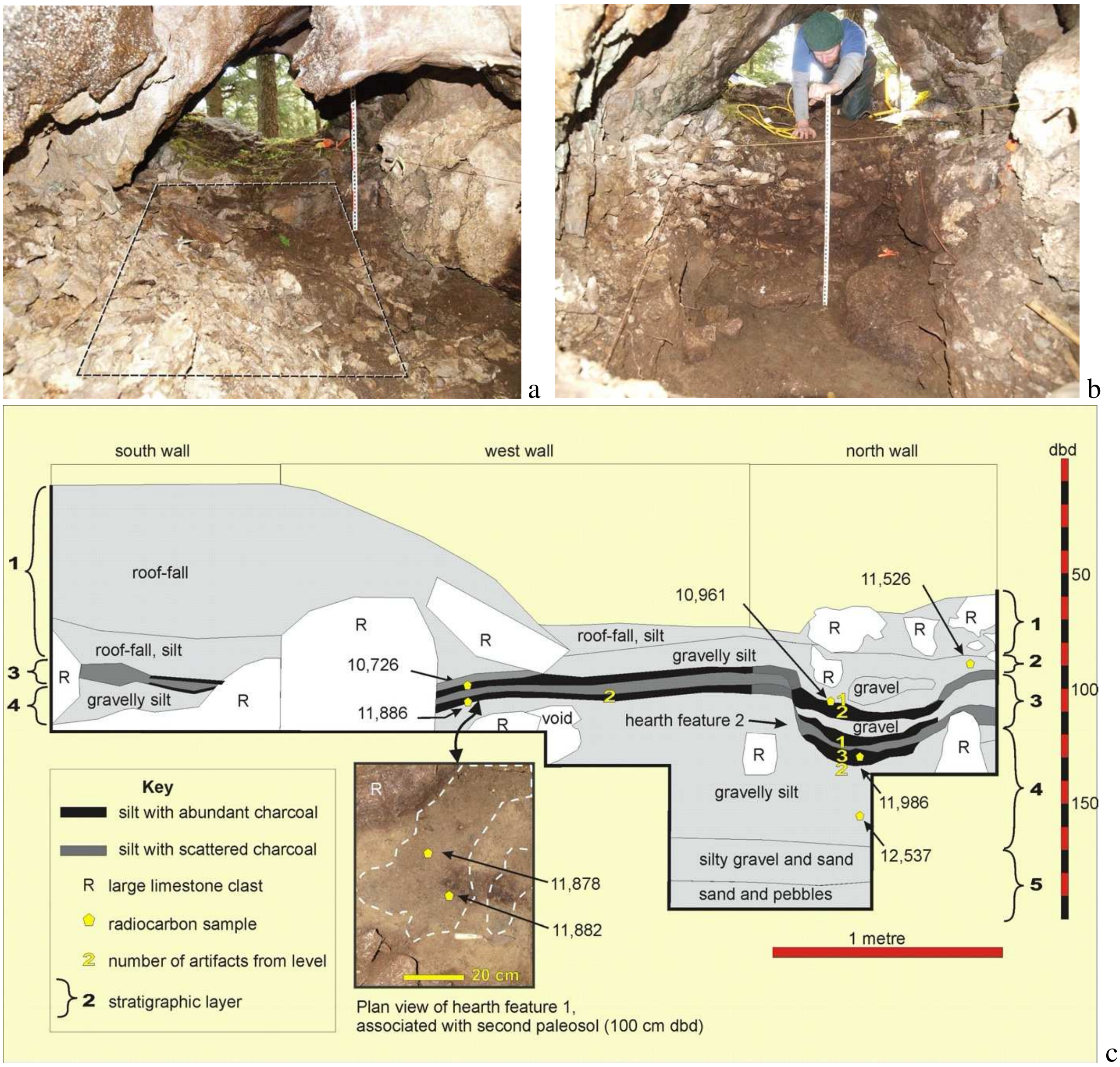


Figure 9 Southerly facing view of Gaadu Din 2 entrance prior to (a), and upon completion of (b) test excavation 6/7 (dashed line); Test Unit 6/7 profile adapted from Fedje et al. 2011 (c). Dates are median calendar ages per Table 6.

Stratigraphy

Stratigraphy at Gaadu Din 2 is best expressed in the area of Unit 6/7. Here the sediment can be divided into five layers that exhibit distinct depositional character (Figure 9). Sediment includes a combination of roof-fall, limestone residue, *in situ* deposited organics, alluvium and colluvium.

The stratigraphically lowest observed sediments (Layer 5) appear to have been deposited when water was actively flowing southeasterly from the back passage(s) out through the Front Passage and the area of the present cave entrance. Sometime prior to 12,020 years ago Passage C

developed sufficiently to capture Gaadu Din 2 stream flow and deposition in the Front Passage became limited to occasional gravel washes overtopping the low bedrock sill at the west end of that passage (Layer 4). These alluvial washes were carried across the gently sloping passage and deposited up against the large roof-fall clasts at the cave entrance. By 12,000 years ago these washes attenuated and deposition just inside the cave entrance became largely limited to silt derived from sheetwash, and limestone dissolution (Layer 3). Shortly after 10,800 years ago one or more episodes of alluvial gravel washes buried the silt layer (Layer 2) and the cave entrance collapsed (Layer 1).

Dating

In total, 11 organic samples from Gaadu Din 2 have been radiocarbon dated (Table 6). In Unit 6/7 internally consistent dates, co-occurrence of exotic chert flakes and concentration of lithic artifacts in well-defined paleosols (Figure 9c, Table 6) demonstrate good stratigraphic integrity for Layer 3. The underlying date of ca. 12,540 years ago from Layer 4 is chronologically consistent. The date of ca. 12,970 years ago, from the interface between the dark silt of Layer 1 and the Layer 2 gravel washes (obtained from a 2007 exploratory test (EU3) located near Unit 6/7) overlies the six internally consistent paleosol/hearth dates (ca. 12,540 to 10,730 years ago) and likely represents redeposition of old charcoal from further in the cave system. Similarly, the bear bone date of ca. 11,520 years ago appears to stratigraphically overlie a hearth lens dating to ca. 10,960 years ago. However, orientation and context indicate this bone has been displaced by a large roof-fall clast. The range of dates recovered is consistent with an interpretation of the cave entrance having collapsed in the early Holocene and remaining closed until very recently.

Table 6. Radiocarbon Dates from Gaadu Din 2 Cave

Excavation unit, lab#	Layer or depth below surface (dbs)	Sample	Material	D ^{13}C	D ^{15}N	^{14}C age	**Cal years Range (2 sd)**	**Cal years median probability**
EU2 (25x25 cm test)								
UCIAMS40880	1 cm dbs	EU2-1	Charcoal			10,220±30	11993-11762	11890
EU3 (25x25 cm test)								
UCIAMS40881	5 cm dbs	EU3-5	Charcoal			11,030±25	13073-12844	12966
EU4 (25x25 cm test)								
UCIAMS40882	14 cm dbs	EU4-17	Charcoal			10,295±25	12438-11885	12018
EU6/7 (1x1.8 m excavation)								
UCIAMS49181	Layer 2	EU6-8a	Charcoal			9,485±15	11059-10604	10726
UCIAMS49183	Layer 2	EU7-10	Charcoal			9,530±15	11068-10707	10961
UCIAMS55099	Layer 2	EU7-A3	Bear bone	-20.8	1.0	10,025±45	11747-11311	11526
UCIAMS49182	Layer 3	EU6-8b	Charcoal			10,215±20	11945-11817	11886
UCIAMS55083	Layer 3	EU6-D8b	Charcoal			10,205±20	11924-11766	11878
UCIAMS55084	Layer 3	EU6-B8b	Charcoal			10,210±20	11944-11769	11882
UCIAMS56932	Layer 3	EU7B15	Charcoal			10,280±25	12429-11830	11986
UCIAMS56933	Layer 4	EU7B20	Charcoal			10,530±20	12662-12479	12537

1) The quoted age is in radiocarbon years using the Libby half-life of 5568 years and following the conventions of Stuiver et al. (2020).

2) Sample preparation backgrounds have been subtracted, based on measurements of samples of ^{14}C-free whalebone. Backgrounds were scaled relative to sample size.

3) Calendar ages were calculated using Calib 8.2 (Stuiver et al. 2021)

4) d13C and d15N values for bone were measured to a precision of <0.1‰ on >10kD ultrafiltered collagen, using a Fisons NA1500NC elemental analyzer/ Finnegan Delta Plus stable isotope ratio mass spectrometer

Paleontology

A small vertebrate assemblage was recovered from this site. Mammals were limited to a single bear bone (black bear based upon size and ^{13}C) and 100 bone fragments not identifiable to

species (Table 7). A small number of bird bones were recovered from the cave floor or upper few centimetres of sediment. A few identifiable bird and fish bones were recovered from excavation Layer 2 (Table 3).

Table 7 Gaadu Din 2 Faunal Remains by Excavation Layer

	Layer 2	Layer 3 upper	Layer 3 lower	Layer 4	Total
Bird					
Alcid (sm)	1	2			3
Ancient murrelet	1				1
Unidentified bird	3	1			4
Fish					
Greenling sp	1				1
Rockfish sp	4				4
Sculpin sp	1				1
Unidentifiable fish	31	2			33
Mammal					
Bear sp. (med/lg)		1			1
Carnivore sp.			1		1
Rodent (vsm)	2				2
Undet.mammal	82	8	2	5	97
Gastropod					
Robust lancetooth	2				2
Total	128	14	3	5	150

Taphonomy

Bone preservation was poor at Gaadu Din 2. The single large bone was in very poor condition despite being in direct contact with a limestone boulder. The cave sediments recovered from Unit 6/7 are slightly basic (pH = 7.65 – 7.90). As soil pH is benign to preservation, poor preservation of recovered bone and a paucity of bone in general may result from fluctuating groundwater levels, microbial action and/or extended surface exposure (cf. Cox and Mays 2000; Bocheranens et al. 2008). As this is interpreted as a temporary camp or shelter, the paucity of bone, especially larger mammal bones, may also reflect discard of refuse downslope of the entrance and cleaning of the living area.

Artifacts

Surface collection and testing produced a small assemblage of lithic artifacts. This includes two bifaces, three biface fragments and eleven resharpening flakes (Table 8, Figure 10).

Bifaces (N=5)

A complete stemmed point manufactured from a yellow-brown chert was recovered from the surface of EU2 (Figure 10a). The point was covered on one face in a thin coating of calcite. The point is foliate with a broad rounded base and a well-defined heavily ground contracting stem. Stem characteristics, including heavy grinding of the broad haft area, suggest the point was set in an end-socketed haft (Fedje et al. 2008; cf. Musil 1988; Galm and Gough 2008). Final flake scars exhibit a collateral pattern.

A complete biface (Figure 10d), partially exposed by a water drip, was recovered from EU4. This artifact was manufactured from a dark grey argilliceous siltstone.

Two biface fragments recovered from Hearth Feature 1 in EU6/7 appear to be projectile point tips (Figure 10b, c). One is a finely pointed snapped tip manufactured from grey chert and the other is the distal end of a point made from a grey volcanic tuff. The tuff specimen exhibits an impact flute scar while the basal end of the fragment exhibits a snap fracture. A third

fragment, recovered from the upper part of Hearth Feature 2, was manufactured from grey argilliceous siltstone but is too small to be classed higher than biface.

Resharpening flakes (N=11)

Three biface resharpening flakes were recovered from test units and eight from Excavation Unit 6/7 (e.g., 10e-h). The EU6/7 specimens include two yellow chert flakes from the upper lens of Hearth Feature 2 and five grey argilliceous siltstone flakes from the lower lens of the same hearth.

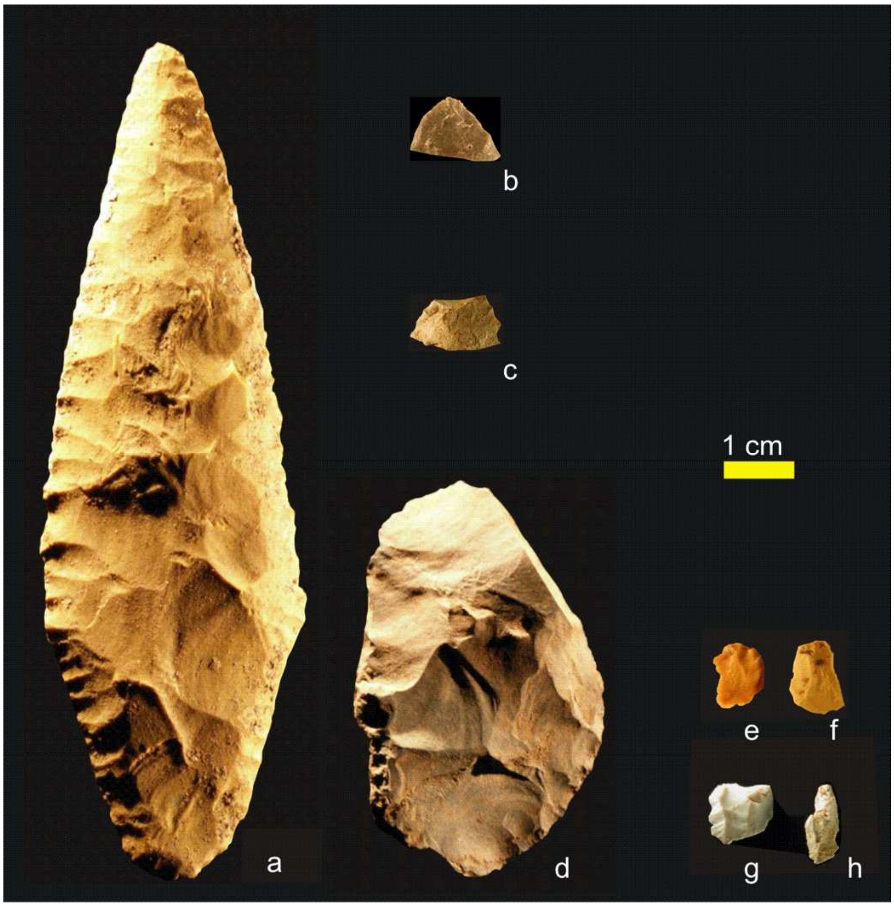


Figure 10 Gaadu Din 2 bifaces (a-d) and examples of biface resharpening flakes (e-h)

Raw material sourcing

The lithic materials represented at Gaadu Din 2 include cherts not seen among the 50,000 plus lithic assemblage from the earliest Holocene Richardson Island (10,500-10,000 years ago) and Kilgii Gwaay (10,700 years ago) campsites (Fedje et al. 2005a, b). The yellow to yellow-brown cherts are distinctive and may derive from a similar source to the 'creamy white to yellow-brown' chert points dating to ca. 12,600 years ago at K1 Cave (Fedje et al. 2008). The white chert flakes may represent a variant of this as well. High quality chert is rare in southern Haida Gwaii although a potential source is known to underlie the Karmutsen formation (Hesthammer et al. 1991). Outcrops of these chert-rich Permian age sediments only reach to a few metres above modern high tide but were likely more extensively exposed with lower sea levels. Grey

argilliceous siltstone is common in archaeological assemblages in southern Haida Gwaii. Similar material has been observed at a number of bedrock outcrops on the east coast of Moresby Island.

Features

Two hearth features were identified during excavation of Unit 6/7, including a shallow basin hearth on the east side of the unit and a deeper basin hearth on the west side. Feature 1 is a shallow basin hearth associated with the lower of two paleosols assigned to Layer 3 (Figure 9c) and dates to ca. 11,880 years ago. It was 10 cm deep at its thickest point and contained abundant charcoal, two biface tips, a fragment of calcined bone and the tip of a carnivore tooth. Feature 2 is a more deeply excavated hearth (Figure 9) and exhibits three lenses with abundant charcoal. The lowest charcoal lens dates to 11,990 years ago. It contained six lithic artifacts and one mammal bone fragment, unidentified as to species. The middle lens contained no artifacts or bone. The upper lens contained three artifacts and was dated to ca. 10,960 years ago. Two small concentrations of charcoal at 160 cm below datum may represent an expedient hearth feature but no artifacts were recovered in association. A date of ca. 12,540 years ago was obtained on charcoal from one of the concentrations (Figure 9).

Summary

Preliminary investigation at Gaadu Din 2 Cave suggests the cave was intermittently used by people as a hunting camp or refuge between ca. 12,500 and 10,700 years ago. This activity is suggested by recovery of formed tools and evidence of on-site tool maintenance.

The paucity of faunal remains is surprising relative to that seen at other karst caves in Haida Gwaii. The basic character of the excavated sediments suggests acidic water table fluctuations and freeze-thaw events are likely the primary contributors to poor bone preservation. As such, the possibility of a bear lair, den or hunting site such as was evident at K1 and Gaadu Din 1 caves (Fedje n.d., Fedje et al. 2004; Fedje and Sumpter 2007) cannot be ruled out. All artifacts from Gaadu Din 2 are conformable with hunting related activity, including hunting points, bifaces suitable for butchering and a number of resharpening flakes from biface maintenance.

Discussion

Paleontology and Environment

Several of the animal species recovered at K1 and Gaadu Din 1 caves provide proxy data on predator-prey relationships and on paleoenvironments, including climate, vegetation and landscape change.

Mammals

Brown Bear

A ca. 17,200 years ago date on brown bear from K1 Cave (Ramsey et al. 2004) suggests that this species may have survived the last glacial period in a local refugium, however, there is no further evidence for the species' presence until the 13,400 to 11,300 record presented here. The timing of extirpation of brown bear from Haida Gwaii is not known with certainty as it is present until at least 11,300 years ago when the paleontological record at Gaadu Din 1 tapers off. Brown bear clearly survived the effects of the Younger Dryas cold interval but, considering their ecological niche requirements, rapid treeline rise ca. 11,000 years ago (Pellatt and Mathewes 1997) may

have reduced key upland habitat to the point where survival was untenable. As well, post-Younger Dryas warming may have lowered the abundance of anadromous fish populations (Chatters et al. 1995; Butler et al. 2004; Ishida et al. 2001; Finney et al. 2002) that were likely an important part of their diet.

Ancient DNA analysis was conducted on a small sample of bear bones from Gaadu Din 1 (Salis et al. 2021). This analysis shows that several of the brown bears belong to Clade 2a, which appears to have arrived from Beringia sometime between 29,000 and 14,000 years ago (Salis et al. 2021). The presence of brown bear implies establishment of an ecological niche extending from Beringia to Haida Gwaii that would have also been suitable for humans. Appearance of Clade 2a bear in Haida Gwaii and on the Prince of Wales archipelago by 13,600 (this paper; Salis et al. 2021; Lesnek et al. 2018) implies a viable coastal entry before this time. The ca. 17,200-year-old brown bear from K1 Cave has not been subject to aDNA analysis but its presence suggests the possibility of very early entry or a refugium. By contrast, 14,500-13,700-year-old brown bear bones from northern Vancouver Island have been identified as Clade 4, likely moving there from the south (Steffen and Fulton 2018).

Black Bear

Black bear is the only extant large land mammal native to Haida Gwaii. It remains contentious as to whether this species survived the last glacial period in a nearby refugium (Byun 1999) or arrived via the south coast (Demboski et al. 1999) and the narrow paleo-Hecate Strait some time prior to 13,300 years ago. A pine parkland environment was established by 14,000 years ago and spruce forests by ca. 13,000 years ago (Lacourse and Mathewes 2005; Lacourse et al. 2005). Brown bear are adapted to tundra and open plains whereas black bears normally live in a forested environment (Wooding and Ward 1997). It may be that black bears arrived from the south along with spruce forest communities sometime around 13,500 years ago (Tables 1, 3). Stable isotope data for select Gaadu Din 1 specimens support species identification, provide proxy data for their diet and support environmental reconstruction. All black bear specimens measured had delta 13C isotopes values ranging from –20.2 to -21.7 while those identified as brown bear ranged from -15.6 to -17.5. The black bear values indicate a strongly terrestrial diet while those on the brown bear suggest a mixed marine and terrestrial diet. This is consistent with the data recovered from these species in southeast Alaska (Heaton and Grady 2003; Lesnek et al. 2018). The strongly terrestrial signature of the black bears was unexpected as modern black bear in Haida Gwaii appear to be very maritime oriented. The disparity may result from brown bear (and probably humans as well) occupying the maritime niche and largely relegating black bear to inland habitat. The Gaadu Din 1 data also suggests that black bears were an important prey for brown bears.

Ancient DNA analysis of a small sample of 13,300 to 12,300-year-old black bear bones identified two as Coastal Clade black bear (Salis et al. 2021).

'Cave Dens'

The abundance of bone (especially black bear and salmon) between ca. 13,000 and 11,500 years ago may, in part, be a consequence of Younger Dryas environmental conditions encouraging use of caves, where very low winter temperatures would have been moderated by geothermal energy, for shelter and denning. With climatic amelioration, after ca. 12,000 years ago, bears could revert to more typical denning and lair behaviour such as the use of excavated dens, hollows under the base of trees and other small natural shelters. Thus, environmental change may explain ca.

12,000 years ago attenuation of sedimentation and large mammal activity at these caves. At Gaadu Din 1, as at K1 cave (Ramsey et al. 2004; Fedje et al. 2004), there is evidence suggesting both denning and predation or introduction of prey. Elsewhere, records show that brown bears prey on denning black bears and on other brown bears (Ross et al. 1988, Smith and Follmann 1993). They have also been documented carrying kills or scavenged animal carcasses into their 'nests'. Although, typically, bears do not eat or defecate during denning, they do when using a den site as a lair or 'nest' during transitional seasons (McLaren 2005). The evidence for large bone-rich scats at Gaadu Din 1 suggests that large carnivores (likely brown bear) used the cave as an everyday lair as well as for hibernation related denning.

Caribou

Caribou was present at K1 Cave (Table 1, Lindqvist 2020) but not identified at Gaadu Din although one unspeciated ungulate exhibited a relatively heavy d13C value (-19.6) which would be consistent with that of caribou (Table 3; Munizzi 2017; Lesnek et al. 2018). All of the caribou elements complete enough to judge size were of typical woodland caribou size. This species persisted on Haida Gwaii through the Holocene (Byun et al. 2002; Spalding 2000; Wigen 2005). Apparent absence at Gaadu Din 1 may relate to sample size as the environment of southern Haida Gwaii would have been suitable for Caribou from early post-glacial time through to the time of closed forest development ca. 12,000 to 11,000 years ago.

Deer

Deer were not known to have been present on Haida Gwaii before introduction by missionaries at the beginning of the 20th Century. At Gaadu Din 1 seven dates on deer and deer-size ungulates, range between ca. 13,150 and 12,810 years ago (Table 3). A deer-size ungulate from K1 Cave produced a similar age of ca. 12,800 years ago (Table 1). Deer may have arrived on Haida Gwaii during a time of climate amelioration around 13,500 years ago when low sea levels resulted in a very narrow separation (and possibly a landbridge) between the archipelago and the B.C. mainland (Fedje et al. 2005c). Although paleontological sample sizes are not large, the absence of deer younger than ca. 12,800 years ago suggests the possibility of extirpation around this time. This timing is approximately coincident with the beginning of the Younger Dryas cold interval. From ca. 12,900 to 11,700 years ago the regional climate was wetter and much colder than present. This resulted in significant environmental changes (Mathewes 1993; Paterson et al. 1995; Hetherington and Reid 2003) that could have been disastrous for a cold-sensitive species such as deer. Deer cannot survive if temperatures remain below freezing or snow depth exceeds ca. 30 cm for extended periods of time (Wilson and Hills 1984; Hanley 1984). On an island archipelago such as Haida Gwaii their last refuge under deep snow conditions would be the beach and beach fringe forest (Hanley 1984) where they would be easy prey for carnivores and people. There are numerous examples of local to regional extirpation of deer during unusually harsh winters (Wilson 1999; Edwards 1956). In most areas this results in a temporary absence as the species rapidly recolonizes the area from lowland or geographically distant populations. However, in the case of Haida Gwaii there was little lowland to migrate to and if regional extirpation occurred repopulation would have been impossible as rising sea levels had separated Haida Gwaii by several kilometers of increasingly frigid waters from the mainland by ca. 13,000 years ago.

The deer and unspeciated ungulates returned isotopic values (Tables 1, 3) midway between the deer (ca. -25) and caribou (ca. -19) values Heaton and Grady (2003) obtained for the

respective southeast Alaska species. The very light isotopic signature for the southeast Alaska specimens is suggested to result, in part, from a canopy effect wherein carbon-dioxide is recycled within the forest resulting in low delta 13C for understory plants and, in turn, deer. The Southeast Alaska deer analyzed are younger than 9200 years ago, at which time coastal rainforests had been fully established (Heaton and Grady 2003). The Gaadu Din 1 values fit those for deer on an open landscape such as the pine parkland characterizing Haida Gwaii from 14,000 to 13,000 years ago (Drucker et al. 2008; Lacourse and Mathewes 2005).

A sample of ungulates from K1 and Gaadu Din 1 caves was subject to aDNA analysis by Charlotte Lindqvist (Lindqvist 2020). Of the 13 specimens analyzed 9 were identified as blacktail deer and one as caribou (Table 8).

Table 8 Haida Gwaii ungulate aDNA results from Lindqvist (2020)

Site	Provenience	Osteometric identification	Genetic ID	Comments
K1	S11/AB/6a	deer	BTD	Complete mitogenome
	S11/AB/6b	ungulate	BTD	PCR
	S11/AC/5b	deer	BTD	PCR
	S11/BB/4	deer	NA	PCR (poor data, excluded; sample insufficient)
	S11/BB/5	caribou	caribou	PCR
	S11/BC/4	ungulate	BTD	PCR
	S11/BD/4	deer	BTD	PCR (poor data, excluded)
	S11/CB/4	deer	NA	PCR (poor data, excluded; sample used up)
Gaadu Din	7/F/5	483: ungulate	BTD	PCR
	8/A/2	397: ungulate	BTD	Complete mitogenome
	8/A/9	818: ungulate	BTD	Complete mitogenome
	8/C/6	389: ungulate	NA	PCR (poor data, excluded)
	11/B/1	1975: deer	BTD	PCR

BTD – blacktail deer

Canids

The three canid teeth from Gaadu Din 1 are from adult animals that are, based upon morphology, either small dog or fox. The premolar compares most closely to dog while the canines fit well with those of both dog and red fox and the teeth are too large to be arctic fox (Susan Crockford 2005 pers. comm.) All three specimens likely come from the same animal as they were recovered in close proximity and, the two dated teeth have overlapping age ranges at ca. 13,100 years ago and near-identical 13C and 15N values (Table 3). The only canid known to have lived on Haida Gwaii is domestic dog with the oldest known dating to ca. 5,000 years ago (Christensen and Stafford 2005). The stable isotope results from the dated teeth suggest a strongly marine diet as is typical for coastal dogs and foxes (Barta 2006). Early post-glacial evidence of red fox on the Northwest Coast includes specimens dating from 14,400 to 12,790 years ago from Shuká Káa cave in the Prince of Wales Archipelago of southeast Alaska (Heaton and Grady 2003; Lesnek et al. 2018). Heaton and Grady (2003) suggest this species may have been extirpated from that area

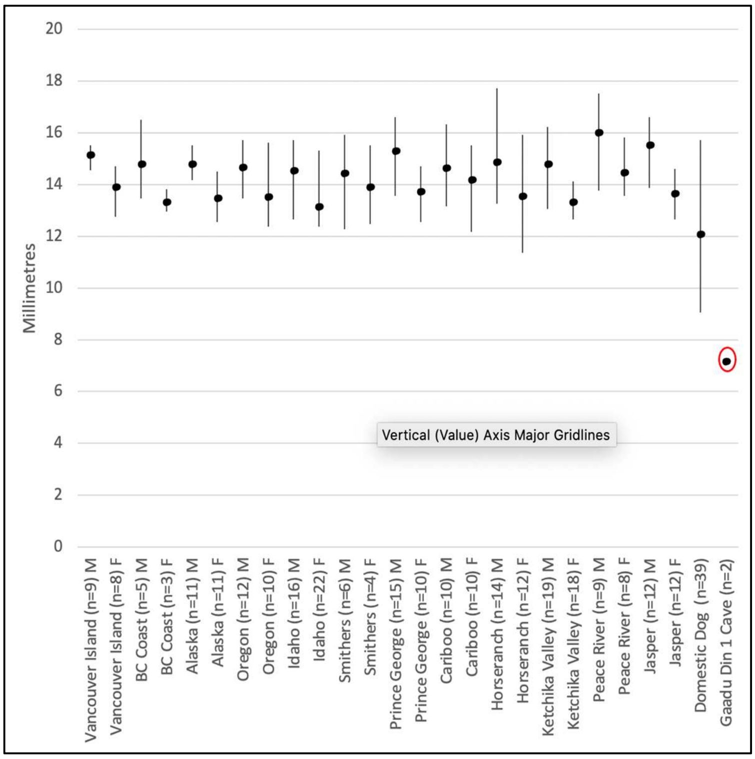
as a result of early Holocene forest development. No pre-Holocene dogs are known for the northern Northwest Coast.

Barta (2006) conducted aDNA analyses on two of the teeth. She determined the ca. 13,100 years ago premolar to be haplotype W (haplotype D6 per Leonard et al. 2002 which is included in haplotype B1 per Van Asch 2013) domestic dog which agrees with the osteometric identification by Crockford. This indicates that domestic dog was present on Haida Gwaii by ca. 13,100 years ago. On the second tooth, no aDNA was able to be recovered. The haplotype D6 premolar is from one of the oldest domestic dogs known from the Americas and its radiocarbon age and aDNA results suggest association with a founding population (cf. Leonard et al. 2002; Witt et al. 2013; Van Asch et al. 2015).

We compared the base pair sequence, (mt D-Loop sequence *Canis familiaris* hapW that Barta (2006) was able to acquire from the Gaadu Din 1 tooth to accessioned sequences in Genbank using BlastN (Zheng Zhang 2000). Matches with zero base pair deviations were found to include both grey wolf (*Canis lupus lupus*) and dog (*Canis lupus familiaris*). The wolf haplotype for this sequence is referred to as Lu7 (Leonard et al. 2002) and/or Clu32 of wolf Clade IV (Ersmark et al. 2016). The dog haplotype for this sequence is referred as being haplotype D6 of subclade B1 (Leonard et al. 2002; van Asch et al. 2013).

Contemporary Lu7 wolves have been identified in western Asia and eastern Europe. Overall, it appears to be absent from far east Asian and American wolf populations. It has been suggested that the restricted geography of this wolf haplotype is the result of male wolves breeding with female B1 dogs, thus establishing a dog haplotype within wolves (Vila et al 1997). Contemporary wolves from the coast of British Columbia are from haplotypes Lu38 and Lu 68 (Munoz-Fuentes 2010) which differ from the Gaadu Din 1 sequence by two and three base pairs respectively.

Significantly, several dog breeds that have genetic evidence of being extant to the Americas have this same haplotype including: Mexican chihuahua, xoloitzcuintli, perro sin pelo and free-ranging Carolina dogs (van Asch 2013). Haplotype D6 dogs are rare in archaeological contexts from North America (e.g. Witt et al. 2015; da Silva Coelho 2021) but are reported from 1400 years ago in Mexico (AY163889)(Leonard et al. 2002). They are also present between 2,500 and 500 years ago in Taiwan on other side of the Pacific Rim from Gaadu Din (KY798513)(Creig et al. 2018). In our opinion, the restricted geographic range of Lu7 wolves to western Asia and eastern Europe, and a lack of evidence of it in the Americas, suggests that it is unlikely that the Gaadu Din 1 element can be ascribed to the wolf taxa. Further to this, the evidence for the D6 haplotype from a pre-Columbian archaeological context and its presence within extant American breeds reveals to us that that the Gaadu Din 1 example is a dog. This evidence is further supported by the very small size of the Gaadu Din 1 teeth relative to North American wolves (Figure 11).



Population	Min	Max	Mean
Vancouver Island (n=9) M	14.6	15.5	15.13
Vancouver Island (n=8) F	12.8	14.7	13.89
BC Coast (n=5) M	13.5	16.5	14.78
BC Coast (n=3) F	13	13.8	13.3
Alaska (n=11) M	14.2	15.5	14.77
Alaska (n=11) F	12.6	14.5	13.46
Oregon (n=12) M	13.5	15.7	14.64
Oregon (n=10) F	12.4	15.6	13.52
Idaho (n=16) M	12.7	15.7	14.53
Idaho (n=22) F	12.4	15.3	13.14
Smithers (n=6) M	12.3	15.9	14.42
Smithers (n=4) F	12.5	15.5	13.9
Prince George (n=15) M	13.6	16.6	15.28
Prince George (n=10) F	12.6	14.7	13.71
Cariboo (n=10) M	13.2	16.3	14.62
Cariboo (n=10) F	12.2	15.5	14.17
Horseranch (n=14) M	13.3	17.7	14.85
Horseranch (n=12) F	11.4	15.9	13.53
Ketchika Valley (n=19) M	13.1	16.2	14.78
Ketchika Valley (n=18) F	12.7	14.1	13.32
Peace River (n=9) M	13.8	17.5	15.99
Peace River (n=8) F	13.6	15.8	14.44
Jasper (n=12) M	13.9	16.6	15.51
Jasper (n=12) F	12.7	14.6	13.63
Domestic Dog (n=39)	9.1	15.7	12.07
Gaadu Din 1 Cave (n=2)	7.12	7.2	7.16

Figure 11 Comparison of measurements of maximum anteroposterior diameter of upper canine at enamel line - western North American wolves and wolf-like domestic dogs (from Friis 1985), and fossil canines from Gaadu Din 1 Cave.

Marine Fish and Birds

Marine fish and birds are rare at K1 Cave but abundant in the upper few centimeters of sediment at Gaadu Din 1. Most of these fish and birds are small, of a size typical of river otter prey. The likelihood of introduction by otter is supported by the recovery of otter bone from the surface of the Gaadu Din 1 cave floor. This maritime fauna may date to the time of the maximum marine transgression (Fedje et al. 2005c), between 10,500 and 6,000 years ago, when the ocean shore was only 50 m from the Gaadu Din 1 entrance or, at most, to ca. 11,500 years ago when the ocean was less than 500 metres distant (Figure 12). At 13,500 and 12,000 years ago the ocean was, respectively, ca. ten and three kilometers away and thus, too far for otters or other maritime fishers to be depositing marine-caught fish and birds.

Anadromous Fish (Salmonids)

More than 2,000 salmonid bones were recovered from the Gaadu Din 1 excavations. These are among the earliest post-glacial specimens known for the Northwest Coast. They date from at least 12,700 to 11,500 years ago. These fish were most likely brought to the cave by large carnivores such as bears or canids (cf. Erlandson and Moss 2001) as the bones are in very good shape and many vertebrae exhibit large spines still attached, rather than being chewed up as would be expected for smaller carnivores such as otters and weasels. The nature of the cave (small steeply descending tubular entrance, low ceiling) and the distribution of the salmonid bones (most at back of chamber) argue against transport by raptors. The source for these fish, during the period of low sea levels before 11,500 years ago, would likely have been spawners in

the small paleo-lake just southwest of the cave or one of the nearby paleo-creeks identified from swath imaging (Figure 12). The creeks, on the east and west side of Huxley Island, both exhibit a low gradient and no obstacles to spawning fish. It is unlikely these fish would have been ocean caught as the sea was at least three kilometers distant at 11,500 years ago and at least 10 km away at 13,000 years ago. If they are spawning this far upstream from the ocean shore, they might be expected to be cohoe, spring, sockeye and trout (especially sockeye if spawning in the environs of the paleo-lake).

Ancient DNA analyses of a small sample (n=25) of salmonid (*Oncorhynchus*) vertebrae from Gaadu Din 1 (Rodriguez and Yang 2012) identified 20 as sockeye salmon (*O. nerka*), two as pink salmon (*O. gorbushca*) and three as rainbow trout or steelhead (*O. mykiss)* or cutthroat trout (*O. clarkii*).

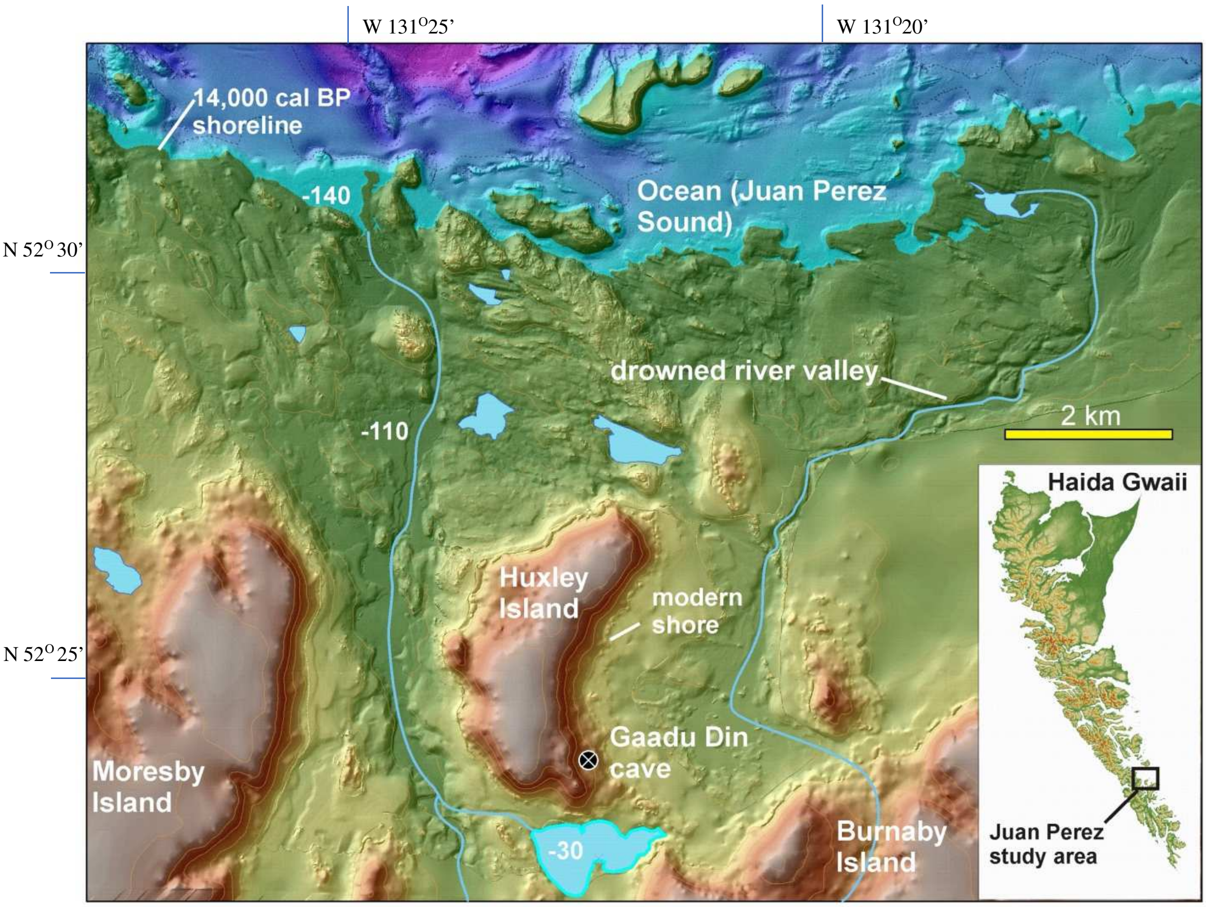


Figure 12 Gaadu Din cave paleo-landscape at ca. 14,000 years ago. Modern features are shown in red tones. Drowned 14,000 years ago landscape is shown in green tones. Depths are in metres below modern sea level. Contour intervals are 50 m. Base image prepared by Patrick Bartier.

This assemblage implies significant salmon productivity on the northern Northwest Coast during the early post-glacial. These fish represent an important resource available to animals and to humans at this early time. The strong marine signature in brown bear and canid remains from Gaadu Din 1 is likely at least in part to be the result of a substantial salmon diet during the spawning season. For people, these fish would have provided an important and predictable food

source, as has long been known from the more recent archaeological record. Salmon may have been especially important to bears and people during Younger Dryas time (ca. 12,900 to 11,700 years ago) when availability of some resources (e.g., ungulates) may have been constrained. The colder water conditions of Younger Dryas times may have been beneficial to the productivity of salmonids on the Northwest Coast area as opposed to warm intervals, such as the early to mid-Holocene hypsithermal interval and modern global warming scenario, for which evidence suggests significantly reduced range (Ishida et al. 2001; Finney et al. 2002; Butler and O'Connor 2004; Chatters et al. 1995; Flemming and Jensen 2002). The record from Gaadu Din and K1 caves, and from offshore sampling of drowned paleoshorelines (Fedje and Josenhans 2000), suggests that although the Younger Dryas climate may have been significantly colder than today, food resources, other than ungulates, available to bears and people may have been relatively plentiful (Fedje et al. 2011a).

Archaeology

There is no evidence that people were active in the K1 Locus 11 chamber. The spear point bases recovered during excavations may have been introduced to the cave by wounded bears who either pulled the spears out in the safety of the cave or died there of their wounds, leaving the artifacts and their bones on the cave floor. Likely, bear hunting at K1 took place just outside the Middle Entrance or outside of a, now blocked, entrance immediately east of excavation unit 11AB.

Human use of Gaadu Din 1 was likely primarily associated with bear hunting immediately outside the cave entrance. The bone point, broken stone spear point and the complete point may have all been brought into the cave by wounded bears. Canid remains and scattered charcoal in the cavern would fit well with the ethnographic hunting techniques described by Hallowell (1926) and McLaren (2005). In these techniques, burning branches were thrown into a den to smoke out the bear or dogs were sent in to roust the animal whereupon it rapidly emerged from its lair and impaled itself on long spears butted into the earth just outside the cave entrance. The presence of flake tools suggests that, on occasion, bears may have been butchered in the cave, possibly for facilitating their removal through the narrow cave entrance, however, no bones exhibit clear evidence of cut marks or burning, canines have not been preferentially removed, and the element distribution is similar to that expected from complete carcasses. The apparent absence of evidence of human agency in the elements recovered suggests that such activities must have been rare. This lack of cut marks is also consistent with ethnographic principles of respect for hunted bears, who were believed to have offered themselves to humans and whose liminal status as animal kin afforded them respectful mortuary treatments (Hallowell 1926; McLaren et al. 2005). Bears killed by humans may have had their entire carcass removed from the cave for culturally-appropriate treatment. The Gaadu Din and K1 bear assemblages are distinct from that recovered from the nearby earliest Holocene (10,700 years ago) archaeological campsite of Kilgii Gwaay (McLaren et al. 2005, Fedje et al. 2005) where many of the bear bones show evidence of butchering and burning.

The paucity of bone at Gaadu Din 2, along with the presence of hearth features and tool maintenance detritus, suggests that this small cave may have been used as a hunting bivouac rather than a hunting site *per se*. Several episodes of biface tool resharpening (cf. spear point maintenance) are evident from debitage recovered from the hearth features, and some of this is of a brown chert very similar to that from which the complete spearpoint was made.

The points from all three caves are foliate. They exhibit slightly more broad bases and wider stems than Kingii Complex foliate points from later time periods (Fedje et al. 2005a, b; 2011b). The smaller Kinggi complex points from Richardson Island and from a number of ca. 10,700-year-old intertidal sites exhibit very narrow bases (1-3 mm) and v-shaped stems (Fedje et al. 2005b, 2008) while those from these cave sites exhibit broad, laterally ground bases and stems. These variables suggest a different haft with the cave specimens associated with relatively thick (ca. 30 to 35 mm diameter) end-slotted spear shafts and the later Kinggi types made for hafting onto (15 to 20 mm diameter) side-slotted atl atl shafts (Fedje et al. 2008). The cave site spear points are quite large and may be special use artifacts not typical of open-air hunting technology. Possibly these may have been attached to a foreshaft for arming a spear. The large size of the cave spears would have been amenable to spear bracing and thrusting in close quarters with a bear.

The sample size is too small to make strong arguments as to underlying lithic technology. However, the lithic assemblage from the three caves exhibits characteristics consistent with those of technologies evident in the 10,700 to 10,000 years ago components from the nearby Richardson Island and Kilgii Gwaay sites (Fedje et al. 2011a, b). A flake tool (Figure 7a) and some of the bifaces (e.g., Figure 7d and 10, d) exhibit evidence of manufacture consistent with that of Levallois-like lithic reduction such as is characteristic of the early Holocene assemblages from Richardson and Kilgii Gwaay (cf. Fedje et al. 2011b; Davis et al. 2012). The spearpoints and biface maintenance detritus at K1 Cave and Gaadu Din 2 exhibit a focus on high quality cherts, possibly from a source on the west coast of Moresby Island. Interestingly, none of the large suite of points, bifaces and biface manufacture and maintenance detritus from the 10,500 to 10,000-year-old Kingii component at Richardson Island and the ca. 10,700-year-old intertidal lithic sites in southern Haida Gwaii are made from chert.

Archaeological Visibility and Site Potential in the Early Post-glacial

The potential for locating any archaeological sites in southern Haida Gwaii dating to the early post-glacial is constrained by the history of deglaciation, sea level and resource availability. Paleoenvironmental data from the Juan Perez Sound area suggests that significant ice remained in the uplands and major valleys as recently as 15,000 years ago, although ice cover was not complete. The Juan Perez piedmont lobe, for example, extended to about 10 km east of Burnaby Island and the area between its end moraine and Moresby Trough shows no evidence of recent glaciation (Shaw et al. 2019). As on eastern Graham Island and Dogfish Bank (Mathewes 1989; Barrie and Conway 1999; Lacourse et al. 2005), this area likely exhibited a tundra-like landscape from ca. 18,000 to 14,500 years ago.

By 14,500 years ago deglaciation was complete in the lowland areas of the east coast of Haida Gwaii. Pine parkland with broad floral diversity is evident at several locales in this area at this time (Lacourse et al. 2003, 2005) with sufficient productivity for brown bear. By 13,500 years ago a diverse terrestrial, intertidal and anadromous fauna had been established. Additional evidence of human activity can be anticipated from other cave sites in the karstlands of this area, but discovery of early post-glacial ocean shore archaeological sites is less likely because of logistics (deeply drowned) and transgressive erosion. The greatest potential for an early record in this area may be formerly inland landforms at locations where key food resources can be expected to have been abundant. If people were present in the area, and the dog remains from Gaadu Din 1 suggest that this is likely, surviving habitation sites might be expected to be found

on never-drowned lake or river terraces where such resources might be concentrated or, in nearby caves or rockshelters.

The north shore of the paleolake (Figure 12) just southwest of Gaadu Din 1 is one location that appears to offer high archaeological potential. The faunal record from Gaadu Din 1 shows that large mammals, possibly including humans, were obtaining bear, deer and salmon near here ca. 13,000 years ago. The presence of salmon by 12,700 years ago makes this location very interesting as spawning salmon could have been trapped or dip-netted along the exit stream flowing out of the lake or along the ancient rivers on the east and west sides of Huxley Island. The lake was drowned by marine transgression about 11,500 years ago (Fedje et al. 2005c) but is at only 30 m water depth and thus, amenable to conventional underwater archaeological techniques. Detailed modeling, using remote imaging, of the submerged landforms adjacent to the paleolake suggest several possible targets.

Regional Context

Corridors

Data from the Gulf of Alaska, Southeast Alaska, Haida Gwaii, the BC Central Coast and the west coast of Vancouver Island suggest that the outermost Pacific coast, from Beringia to the unglaciated coast of Washington State, was ice-free by 16,500 years ago (Misarti 2012; Lesnek et al 2018, 2020; Shaw et al. 2019; Ramsey et al. 2004; Darvill et al. 2019; Cosma and Hendy 2008; Hebda 2019). Deposition of ice rafted debris and glacial marine sedimentation off the outer coast (via major troughs) continued until ca. 15,000 years ago indicating that deglaciation of the inner coast towards the fjord heads continued until that time (Davies et al. 2011; Cosma and Hendy 2008).

These records provide a strong argument for a coastal corridor being available sufficiently early to account for the ca. 15,000 to 14,000-year-old sites known for the Americas south of the Wisconsin ice sheets (Erlandson et al. 2007; Dillehay et al. 2008; Jenkins et al 2012; Halligan et al. 2016; Waters et al. 2018; Braje et al. 2019; Davis et al 2019).

The karst cave data show that people were living on this island archipelago 12,600 years ago based on artifacts, and likely by 13,100 years ago based on the presence of domestic dog at that time.

We note that First Nations traditional histories speak to ‘long ago’ events that appear similar to those identified through scientific work (e.g. Wilson and Harris 2005; Young 2005).

> “In the beginning there was nothing but water and ice and a narrow strip of shoreline”. (Farrand 1916: 883).

> “Then he [Raven-Walking] told only the black bear, marten and land otter to be here [on Haida Gwaii]. And the strip of ocean between [the mainland and Haida Gwaii] was narrow. The tide flowed back and forth in this, and he pushed the islands apart with his feet ... at that time there was no tree to be seen” (Swanton, 1908: 324).

Bear Hunters

The Haida Gwaii karst cave data show that people were hunting bear in this area at least 12,600 years ago. If the ca. 13,100-year-old Gaadu Din 1 dog was part of a hunting team, this tradition (cf. Hallowell 1926; McLaren 2005) may extend back another millennium. It is plausible that

these maritime-oriented people arrived on Haida Gwaii via the same corridor that the Clade 2a brown bears traversed to reach southeast Alaska and Haida Gwaii (Salis et al. 2021).

Conclusions

Investigations of ancient landscapes in the Haida Gwaii – Hecate Strait area have produced significant new data as to the early postglacial environment of the region and highlight the potential for an early human record. This record can be firmly extended to at least 12,600 years ago, and identification of a domestic dog dating to ca. 13,100 years ago implies human presence by that time. We have begun to fill in details about the environment these early people inhabited. It was a dynamic environment of rapidly rising sea levels, faunal extirpations, and forest infill, very different from that of modern Haida Gwaii. All the same, the presence of a variety of mammals, birds and fish dating as early as 13,400 years ago, along with evidence, on nearby drowned beaches, for rich intertidal shellfish beds dating back to at least 13,500 years ago (Fedje and Josenhans 2000) suggests that the area was suitable for people with a coastal adaptation by that time. The arrival of Clade 2a brown bear to this area by ca. 13,400 years ago suggests the coastal corridor was productive and passable to this animal, and by extension to humans (who have many of the same resource needs), by this time, if not earlier. The environmental data retrieved from paleobotany (Mathewes 1989; Lacourse et al. 2004) and paleontology (this paper) suggest a much more diverse interior landscape than that of today, and thus a broader coastal foraging adaptation, could be expected in early post-glacial time. This data, in concert with tools such as elevation models and paleoecology, lets us begun to visualize how people may have used this ancient landscape and how we might best target our search for the very early archaeological record.

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